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RESEARCH IN ENGINEERING COLLEGES

By R. A. SEATON

President of the Society

At the recent Conference on Research at the Corvallis meeting of the Society the discussion brought out clearly that research in engineering colleges benefits four groups: the students, the instructors, the industries, and the general public. The general public is doubtless the principal beneficiary, since the benefits to the other groups are ultimately reflected to the public in new and better services and products and in lower costs. Students benefit from the research directly, through training in research methods and through the inspiration and motivation which contact with research brings. They also benefit indirectly, through better teaching which results from the stimulation research brings to the instructors.

Theses were formerly required of all, or nearly all, seniors in engineering colleges. The primary purpose of this requirement was to develop the initiative and resourcefulness of the student and to give him some insight into research methods, rather than to develop new knowledge. To a considerable extent this primary purpose was accomplished and the thesis work was a valuable part of the training of the engineering student. However, as enrollments increased, the demands of thesis work upon the laboratory facilities and equipment became excessive and the instructors were unable to give the necessary amount of individual attention to students doing thesis work. This situation, and pressure for inclusion of additional courses in the curricula, led to the general abandonment of the senior thesis. More recently there has been a tendency toward the revival of the senior thesis in some engineering colleges, not as a fixed requirement for all seniors, but as an option available to certain senior students who have special interest in, and ability for, such work.

With the development of graduate work in engineering colleges, the participation of students in research work assumes a somewhat different aspect. The graduate student brings to his research work a greater maturity and a fuller training than did the senior student. The amount of time usually allotted to work on the master's thesis is several times as great as was allotted to the senior thesis. Conditions are therefore much more favorable for real research work and some really valuable contributions to our knowledge may occasion-

ally result. This is especially true in the case of part-time graduate research assistants who, in return for a modest stipend, extend their graduate training period over more than one year and devote to research activities a considerable fraction of their time in addition to that normally allotted to the master's thesis.

Really adequate research activity in engineering colleges requires more, however, than student thesis work supervised by members of the faculty. There must also be actual research work by the faculty members themselves, with or without the help of full-time research workers. Graduate students and part-time graduate student assistants may be used to help carry on such research work, and if the work is well organized will themselves obtain a maximum of value from participation in such work.

Some kind of a research organization seems desirable—an engineering experiment station or a somewhat similar organization under another name—to provide a definite recognition for research work in the programs of the institutions, to correlate this work, and to provide organized effort for the solution of the common problems of those engaged in such work.

The surveys of the Society's Committee on Engineering Research indicate that as yet far too little attention is being given to research in most engineering colleges. Many institutions with fairly large enrollments of engineering students are doing little or no research work and in many institutions in which research is fairly well developed in certain departments, other departments are entirely inactive in this kind of work. The number of institutions in which there are really any adequate, well balanced, and properly organized programs of research is very small. Why should this condition exist? The costs need not be large, and the benefits are great. Why should not research be regarded as a normal function of the faculties of all departments of all engineering colleges, valuable both for the stimulation and development of students and faculty members, and for the discovery of new knowledge of fundamental principles and their applications for use by engineers and industries in serving the public?

CULTURAL ASPECTS OF ENGINEERING EDUCATION *

By KARL T. COMPTON, *President*

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I think we may assume that engineering education, like all professional education, is basically utilitarian in purpose. Its most direct objective is to train men to engage in those engineering arts on which are based the material side of our civilization. We have devoted a great deal of thought and effort toward making this training as effective as possible. This aspect of our work needs no defense, and so I shall take it for granted, and proceed to another aspect of our work which is not so universally recognized—its cultural value—which will be approached from three viewpoints.

1. *Throughout history, engineering and cultural developments have been fundamentally related to each other.* Probably civil and mechanical engineering are the oldest of the arts, though perhaps comparisons are open to criticism, as illustrated by the story of the engineer, the surgeon and the politician who were arguing for the historical precedence of their respective professions on the basis of the account of creation in the first chapters of Genesis.

The surgeon recited how, in the second chapter. the Lord caused Adam to fall into a deep sleep, during which he extracted a rib and closed up the flesh over the place where the rib was. This, he said, was obviously a surgical operation, performed under an anæsthetic. Then the engineer pointed out that the first chapter told how the Lord took chaos and out of it separated the waters from each other and caused dry land to appear—obviously a job of civil engineering. "Ah," said the politician, "but who made chaos?"

However this may be, it is certain that civil engineering dates from the time when men first made paths through the forest and built habitations. We may define civil engineering as the art of making the earth a fit and convenient place on which to live and move about. Certainly nothing has played a greater role in shaping man's culture than this art, and it is an aspect of culture that will continue as long as man continues on the earth.

Similarly mechanical engineering is an integral part of the cultures of all ages. In fact it is only by their tools that we know the

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cultures of the most ancient peoples, and we designate them as of the Stone Age, the Bronze Age, or now the Age of Steel. In all ages man's culture has found expression in his tools and his cultural development has been limited by them.

In more recent times new branches of engineering have arisen—electrical, chemical, automotive, refrigeration, motion picture, illumination, heating and ventilating, mining and metallurgical, acoustical, etc. Taken together, they epitomize man's progress not only in material things, but in his ability to think logically, accurately and purposefully. It is true that a branch of engineering has arisen in every field in which scientifically sound principles have been discovered and applied to the meeting of some human need or desire. It is true that engineering thus far is practically confined to applications of the so-called natural sciences, since these alone have been reduced to a sufficiently reliable understanding of "cause and effect." In the tremendously important, but complicated, field of human relations, only the foundations are now being laid. It is true that we have a few aspects of engineering in this field, such as industrial, efficiency and sales engineering, but these only scratch the surface. Social Science is not a true science as yet, though it is coming to be one. But when it is developed to the point of accuracy and certainty such that something useful and definite can be done with it, then we may be sure that Social Engineering will become a reality—and a tremendously important one.

Not only have engineering developments been an integral part of cultural progress, but they are basic even to those aspects of cultural progress which are in quite different fields, as in philosophy, art and law. Consider those times in history when the great advances in civilization have been made, such as during the great Egyptian dynasties, the Age of Pericles in Greece, the era of the Roman emperors, the Age of Chivalry in Europe, and the present era. The great advances in civilization have been made by men who had time to think, to experiment, to discuss and to build. Directly or indirectly they were partially freed from the necessity of continued drudgery to provide the bare necessities of life, and they used this time and freedom constructively to think new thoughts and develop new processes.

The key of opportunity for these pioneers of civilization was *increased productive power*. In earlier times this productive power was due to slaves or serfs; now it is due to machinery, driven by the power of coal, oil or water. Then human beings were driven like machines; now, through engineering developments, each man, woman and child is served by the equivalent of fifty slaves working full time. It is to the productive power thus created by engineers that every person now has, potentially, the opportunities for cul-

tural pursuits and development that formerly were possessed only by the favored few. It is to this productive power that we owe the years free for education in our youth, vacations and shortened hours of labor in middle age, pensions and retiring allowances in old age. Productive power is not by any means the chief end of man, but through it the engineer has given to our generation a tremendous opportunity, the opportunity for every person to have even greater cultural advantages and opportunities for further development than were enjoyed by the favored few of past ages.

From this brief historical survey I would draw two conclusions: Engineering has been and will continue to be an inherent, fundamental element in culture. Furthermore, one of the greatest problems now facing mankind, is that of developing the habit, technique and moral sense to use the free time given by modern engineering in ways beneficial to the race. This is essentially a problem of education, and is peculiarly a problem of engineering education, since through engineering was the problem created. On its solution will depend the answer to the question, "Is engineering a benefit or a curse to man?" At the conclusion of my remarks I will make some specific suggestions for handling this problem, but will now approach the subject of culture and engineering from the second viewpoint.

2. *Acquaintance with engineering is an essential part of cultural training.* Thus far I have discussed culture without defining it. Let us now enquire more closely into its real meaning. According to the dictionary, culture is "the training, development, or strengthening of the powers, mental or physical, or the condition thus produced; improvement or refinement of mind, morals or tastes; enlightenment or civilization." There was, not long ago, a time when knowledge of science, and particularly of things useful, was popularly considered foreign and even antagonistic to culture. Literature, music and art held the center of the stage, as well as both the wings. It was a cultural pursuit to delve into a study of the tools and machines of the cave men or the Egyptians, but not to try to understand the science and the machines of the civilization in which we actually live. I suspect that this distorted attitude was due to what the psychologist would call a "defence reaction"—the last stand of respectable ignorance against the inexorable advance of knowledge and its applications.

In recent years this viewpoint has rapidly changed. Science has so permeated our civilization that, even though it be imperfectly comprehended by the majority of people, it nevertheless has every bit as universal an appeal as do literature and art. It is not possible to understand our environment or to live intelligently in it without an understanding of science and engineering.

If anyone doubts this last statement, let him consider carefully any ordinary day of his life, and make an analysis of the points at which his actions, contacts and thoughts are prescribed by the results of engineering. His transportation, mail, telephone, reading, recreation, night life, domestic activities, in fact almost everything that he does, is directly dependent on the work of the engineer. Most people would be astonished to realize how completely this is the case.

I should define culture as "the sympathetic understanding and appreciation of life." Life has various aspects, emotional and intellectual. "Music hath charms to sooth the savage beast." In literature we have access to the finest thoughts and feelings of mankind. Art brings us beauty of form, color and expression. All of these, and religion have power to bring to us a mystical uplift of feeling. Even so do likewise science and engineering. They, too, express symmetry and intellectual beauty of form and relationship. They, too, require imagination. But science and engineering, in addition, possess a power and exercise a discipline which render them unique.

The element of intellectual satisfaction in an engineering job well done should place such work high in the scale of artistic achievement. I suppose that, basically, art is that which gives satisfaction. The lowest forms of art appeal only to the appetites. The most primitive artist was the man who made a good kill, bared his teeth, and bit in for a good meal. His artistic satisfaction in this achievement still survives, so anthropologists tell us, in that most universal signal of pleasure, the baring of the teeth in smile or laughter. Somewhat higher forms of art are those which appeal to the senses, but are not essentially utilitarian, as is eating. Art really reaches a high level when it appeals to the imagination and stimulates thought. Judged by this criterion, a fine bridge, a radio set or a powerful formula are artistic in the highest sense. They possess beauty of form and relationship, they are appropriate in their background and they have almost boundless intellectual relationships. Like other forms of art, they cannot be appreciated without training and study. But to deny the artistic element in an engineering masterpiece and designate it as merely a material arrangement of concrete and steel is every bit as uncultural as to see in a masterpiece of painting only an arrangement of daubs of paint—and more uncultured, since paintings do not form a necessary part of our environment, whereas engineering structures do.

We come now to the third and last approach to culture and engineering:

3. *Engineering education is an excellent general training for life.* It is impossible to make a sharp distinction between utili-

tarian and cultural training. My old professor of Latin used to keep on his blackboard the motto, "The purpose of a liberal education is not to enable you to earn your daily bread, but to make each mouthful sweeter." Yet somehow each mouthful must be got before it can be enjoyed. Conversely, no man undertakes a professional education merely because he wants to make a living, but because he anticipates special satisfaction in making it in that particular way. I think the distinction between professional and liberal education is much overdrawn, and that every man should have an education which contains substantial elements of both features. But the point which I wish to emphasize particularly is that a properly balanced engineering education may be a very definite liberal education and should be more generally considered in that light. Let me elaborate this point.

Recently in a large engineering school there was a young woman student of mining and metallurgy. She took this course, not because she expected to become an engineer, but because she was about to inherit her father's mining business, and she wished to have a fundamental basis of understanding it. For her it was a cultural study, since it was undertaken to give her a "sympathetic understanding and appreciation of life"—the particular life that was in store for her.

In the same, though usually less striking way, an engineering education may be an excellent background for almost any life activity. This is not speculation, but is an actual fact, to which about half of the graduates of our engineering schools are living witnesses—for surveys show that not more than half of the graduates of engineering schools follow their school specialty as a life profession. For them it is the background of vision, training and discipline, and not a utilitarian professional preparation.

The mental discipline inculcated by the study of science and engineering is, I believe, at least as important an aspect of their cultural value as is the acquirement of knowledge regarding our surroundings. Science requires straight and independent thinking. Every hypothesis or idea is capable of definite proof or disproof. The habit of mind that subjects every idea to rigid test is of utmost value. Much of the loose thinking in social, educational, political and economic affairs would be avoided if the workers in these fields could be given a real training in accurate scientific thinking. And engineering training, besides developing habits of scientific thinking, gives the additional valuable habit of accomplishment, the power to marshall all available resources and arrive at the desired result. Scientific and engineering studies possess the same advantages as do the classics in giving a training in precise thought and expression, but in addition they afford training in observation,

in inductive and deductive reasoning, in exact checking of hypotheses and assumptions. At the same time they are the key to the understanding of our environment.

Conclusions.—Granting all that has been said, of what interest to us is the fact that engineering education has profound cultural as well as utilitarian value? The question of engineering education should be of interest not only to us engineers, but to the entire public which lives in an engineering world. Let me therefore close by making several specific suggestions, none of them new, but all of them reinforced by the considerations which have just been discussed.

1. To meet the needs of the student who may study engineering for its general training and cultural value, the curriculum should contain a fair proportion of non-engineering subjects, as English rhetoric and literature, language, history, economics, sociology, psychology and philosophy. A training without some of these is just as warped as one without science and engineering.

2. To meet the needs of that considerable proportion of our students who sooner or later find themselves in positions out of the direct line of their special training, we must lay particular emphasis on training in those fundamental principles which underlie all engineering, and the students outlook also should be broadened by introductory studies in important non-engineering fields.

3. For the benefit of society, as well as for the most efficient work of the engineer, it is essential that the engineer should be trained to think not only of his specific engineering projects, but also of their larger significance in the economic and social order, so that he may be a leader in solving these social problems which his work is creating. For if these social problems are not solved, they will react to curtail or destroy his future activities. To stimulate such an attitude, good introductory courses in economics and sociology should be very helpful—not courses of the cut-and-dried text book variety, but courses in which the real vital points, sore spots and opportunities created by engineering in our modern world are clearly and constructively presented.

The practical problem before engineering educators is that of finding time and place in the curriculum for these and other desirable features. The complexity of engineering has become so great that we have long ago passed the stage at which we can hope even to approximate that early ideal of giving a student knowledge and practice in every aspect of engineering art so as to arm him to meet every possible situation. I think we all frankly admit this, and also admit that such complete training is no longer necessary in our schools, since the necessary detailed training in the technique can usually be best obtained, now-a-days, in the first months of

employment on the job. Yet we still find many traces, in our curricula, of those early days in which every engineer had to be trained to be his own blacksmith, machinist, analyst, etc.

Perhaps I may be pardoned a personal reference bearing on this matter. A couple of years ago I was trying to decide whether to give up the profession of physicist in which I had been very happy for that of engineering educator, in which I had no experience or intimate interest and I went to talk over the matter with an engineer-physicist in whose judgment I had great confidence, a vice-president of one of the greatest engineering industries. He was emphatic in his belief that the old era of engineering had outlived its usefulness; that modern industries in general did not need men who had received college training in the technique of the jobs they were to perform for the industries, but that they did desperately need men who had broad training in fundamental science, who had a basis for incisive and powerful handling of any of a wide variety of problems, and who had been trained constructively to apply their knowledge in some engineering field—it did not make so much difference what that field was; and that tradition was tending to hold the engineering schools behind the more progressive industries. Though realizing that this man's statement is truer in some lines of engineering than in others, there is certainly much truth in it. It suggests the following approach to the problem of the engineering curriculum.

Our surveys indicate that three or four technicians are needed to each engineer. Technical schools have sprung up in considerable numbers to train these technicians. Is it not true that our engineering schools have tended to become hybrids—to attempt to do both jobs: training technicians and training engineers? Do we not carry, as a vestige of past necessity, too much attention to shop practice, routine analysis and testing, forging and the like? Admitting the real educational value of such work, should we not reduce its amount and thus find place in our curricula for more adequate attention to economic business and sociologic studies which will aid in orienting our students in these fields in which their contacts throughout life will be of the most vital nature? I believe that a consideration of relative values makes the answer to these questions obvious.

To sum up, therefore, I believe that we should make more clear-cut the distinction between technical and engineering education; that we should uphold the importance and dignity of the technical schools and advise some so-called engineering schools frankly to recognize their nature and real opportunity as technical schools; that our criteria for real engineering schools should include the best possible basic training in the sciences and fundamental engineering

subjects, with some specialization and with very considerable attention to the place and problems of the engineer in society; and finally that we should recognize that there is a vital cultural element in engineering, whose recognition by engineers should lead to their increased confidence and satisfaction in their work and whose recognition by the public should lead to the increased prestige and recognition which the importance of their work justifies.

MODERN TRENDS IN ENGINEERING *

By DEXTER S. KIMBALL

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The period of depression through which this country is now passing is one of critical examination of all of our national activities; and engineering in all of its phases is no exception to this investigation. With industry at a low level and with thousands of engineers out of work questions and issues that have lain in the background are now thrust to the front with insistent demand for some solution. And it may be that out of the discussion now going on the entire trend of the profession may be definitely altered. In discussing any such changes it must be kept in mind that engineering differs markedly from other professions such as law and medicine. The direct impact of these latter professions upon the individual is for the most part occasional, only, and usually during times of difficulty. They do not enter so intimately into one's daily life as does engineering which touches us in almost every act of our life. Indeed, it is amazing how intimate this contact is and how little this close contact is appreciated. The ease with which all employ highly scientific apparatus such as telephones, radios, automobiles and the endless array of labor and time-saving devices is one of the marvels of the age. The boy of 12 or 14 builds a home-made radio for which performance his New England ancestor would have been hanged or drowned and long before the law will permit him to do so he can operate an automobile, one of the most remarkable productions of this astonishing engineering age. Men, women, and children are engineers to a degree; no other calling approaching engineering in universality unless it may be agriculture. As President W. E. Wickenden has so ably pointed out in his report for the S. P. E. E. on engineering education, the background and history of engineering differs from that of law or medicine and it is unwise, therefore, to draw conclusions from these professions as to the future of engineering.

No less interesting and important is the extent to which engineering methods have made their way into industry and business. Industry itself has become so highly scientific in character that it is dominated by engineering and engineers, and business is rapidly adopting engineering methods. An examination of the curricula

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of graduate schools of business reveals a considerable amount of instruction in methods and practice that had their origin in engineering industries. The term "engineer" indeed has lost much of its old significance. Fifty years ago it was not difficult to define the duties of engineers with some exactness. To-day there is an endless variety of industrial workers who use the title. In addition to the old and well known titles of civil, mechanical, electrical and mining engineer there are sanitary, heating, sales, advertising, oil tempering, management, efficiency, illuminating, lubricating, and automotive engineers and many others too numerous to mention. Engineering appears to have become a *method of thinking* or rather a *method of accomplishing results* in a manner never before known to mankind, and it appears to be permeating every nook and corner of our existence.

This broadening of the field of the engineer has been reflected in the engineering societies. Originally a single society, the American Society of Civil Engineers, sufficed. Then the mechanical engineers split off from the civil engineers, the electrical engineers separated from the mechanical engineers, and for a while the four Founder Societies, so called, representing civil, mechanical, electrical and mining engineering, sufficed for all such purposes. Then came a greater centrifugal movement and a splitting away of smaller groups from these older societies and the formation of others to satisfy new needs. Thus the heating and ventilating engineers, the refrigerating engineers, the heat treaters and other branches of mechanical engineering have set up independent organizations while other groups such as the Society for the Testing of Materials have drawn members from several of the older groups. In addition there are a number of local engineering societies such as the Western Society of Engineers of Chicago and the Engineers Society of Western Pennsylvania, the Engineers Club of Cleveland and others that have had a long and helpful existence.

These engineering organizations have a sound engineering background and have been organized largely to create centers of engineering interest. Social and economic motives have been at least secondary. Specific recognition of the growing importance of the economic side of engineering is seen in the founding of the Taylor Society, the Society of Industrial Engineers, the American Management Association, and the Management Division of the American Society of Mechanical Engineers. As engineering has grown in importance and as competition within the profession has increased, there has been a growing group of consciousness which has tended steadily to project the economic and social problems of the engineer to the front. A natural result of this growing sentiment is seen in the founding some years ago of the American Association

of Engineers and the Society of Professional Engineers of New York, and also in the increasing recognition of the human side of engineering life by the older engineering groups. The Committee on the Economic Status of the Engineer quite recently appointed by the Council of the A. S. M. E. exemplifies this growing sentiment which is finding a place in the deliberations of even the most conservative societies. The greatest manifestation of this sentiment is seen in the formation of the American Engineering Council representing 25 national and local societies with 60,000 members and organized as a means of expressing the opinions of engineers on all national matters on which they are competent to express an opinion. The work of this council has been noteworthy and indicates what the engineers of this country could do if all were united in a single great body. Lastly, there is the rapidly growing sentiment toward registration of engineers which is almost sure to crystallize certain opinions as to the place of engineering in modern life and possibly exert considerable influence upon engineering education.

The picture that the engineering profession presents in this country is, therefore, a complex and confusing one. It has already made the problems of the engineering curricula very complicated and it has been most difficult for educators to steer a safe and sane course through all of these conflicting conditions which industry presents, and for which they must fit their graduates. It is indeed a time for careful analysis and reflection rather than for hasty action. It may be pertinent to raise a few questions as to the probable trends in industry and among the engineering societies in the near future as these are sure to affect our viewpoint as educators.

Barring some new and basic inventions comparable to those that inaugurated the industrial revolution, it is not to be expected in the nature of events that western civilization can make industrial progress at the rate it has developed during the last seventy-five years. Scientific and industrial progress will, of course, continue, but the law of diminishing returns must apply here as elsewhere. In the United States, as in England, industrial progress has been dependent partly upon foreign trade which promises, unless all signs are misleading, to be an increasingly crowded field. The expansion of our population, due to pioneer conditions, is already slackening with a tendency for the rate of increase in population to stabilize. Already we have all the transcontinental trunk-line railroads that we need, our plants for building locomotives, ships, electrical generators, and motors are apparently large enough for our needs. No doubt there will be many advances in productive methods with a consequent cheapening of product and a wider use of the same. With a return to normal conditions, which will no doubt come about, there will be necessarily an increased consump-

tion of food and clothes, and a still wider use of telephones, automobiles, radios, and other consumable goods. The basis of productive industry will, no doubt, become increasingly more scientific, both as to design and actual production, but there will probably be less demand for highly trained technicians, and more for highly trained production engineers and executives with engineering background. A brief study of the growth of such utilities as the telephone, radio, automobile and other mass production products will show that the general pattern of the personnel of such enterprises is, as indicated in the foregoing. And there are no new discoveries or inventions of *economic value* in sight that might give employment to large numbers of highly trained engineers during the period of experimentation and development.

These, and other changing conditions have already reacted upon the profession and are manifesting themselves in three principal ways. The first is a tendency on the part of the major engineering societies toward a higher professional standard for membership. For a number of years past there has been considerable complaining among the younger members of some of the older societies that little or nothing was done by the societies for the economic side of engineering. In the American Society of Mechanical Engineers this resulted in the appointment of a Committee on the Economic Status of the Engineer, already noted, with the formation of similar committees in some of the other groups. Quite recently a joint meeting of these several committees was called to discuss this general problem. The societies represented were:

The American Society of Civil Engineers,
The American Society of Mechanical Engineers,
The American Institute of Electrical Engineers,
The American Institute of Mining and Metallurgical Engineers,
The Society for the Promotion of Engineering Education,
The National Council of State Board of Engineering Examiners, and
The American Institute of Chemical Engineers.

This joint meeting has proposed a new council to be known as the Engineer's Council for Professional Development, the function of which would be to aid and encourage through proper committees the entire program of educating, admitting to the professional societies and proper licensing of the engineering fraternity. This plan has as yet to receive the sanction of the several boards of control of the engineering societies, but the movement is significant.

The second trend is made manifest by the recent appointment of a joint committee representing the four Founder societies, and other important engineering organizations under the ægis of the

United Engineering Societies to consider ways and means of simplifying and consolidating all engineering societies in this country. The American Engineering Council already represents a successful effort in this direction, and if its full purpose can be achieved, engineers in this country will be fully represented in national matters by a powerful organization.

Lastly, there is a strong movement all over this country in favor of the licensing of engineers and it may well be that the first two trends already discussed may both move to make licensing more effective. Quite recently the boards of licensing examiners of the states where licensing and registration are legally required met and formed the National Council of State Boards of Engineering Examiners already alluded to. This Council is now in the field with proposals for uniform licensing examinations and uniform state registration laws. One is naturally led to question the congregated wisdom of such a body considering its possible political origin, but its existence and potential power is with us. It is here that these trends may touch the colleges most sharply, especially if through them the qualifications for licensing and for admission to the professional societies should tend to restrict or qualify the curricula.

Without debating in any way the merits and disadvantages of licensing it should be noted again that the arguments that apply to medicine and law do not apply in their entirety to engineering. The basic and only logical argument for licensing is protection of the public and this is applicable fully to doctors, lawyers, plumbers, marine engineers and others that need such certification. But as already pointed out, the field of engineering is a very wide one and only a comparatively small number of engineering graduates will be employed in activities affecting the safety of the public. The majority of engineers are in no more need of licensing than is the merchant, stockbroker, carpenter or mason. The only other reason that can be adduced for licensing is that of mutual protection and a desire to hold the field for men of superior training as was the practice among the medieval guilds. This in itself may be praiseworthy, but it has little or no precedent in our industrial history. On the other hand, there can be no objection to any reasonable technical requirements that may be set up by national engineering societies to improve the general quality of membership. It may be, however, that too high a standard of qualification may result in the formation of other organizations of lower technical attainments, yet eligible for licensing. Licensing of itself is no assurance against low standards. The shyster lawyer and the medical quack are still with us in goodly numbers despite rigid license laws covering the profession of law and medicine in all states of the Union.

Obviously, licensing of engineers, admission to professional societies and college curricula are likely to be closely related in the future and this fact should engage the attention of all educators. There is one tendency in particular that a consolidated professional engineering attitude might present, namely, an effort to restrict or dominate the curriculum of the engineering colleges as is the case to a certain extent in some European countries. There may appear some tendency to standardize the curricula and standardization of this sort might be in the direction of mediocrity rather than in upgrading. We have already suffered somewhat through state and federal regulation in this respect.

There are in this country two somewhat divergent views as to what the function of university education should be. On the one hand are those who believe that this function should be to develop a comparatively small number of highly trained persons in the leading professions and activities of life such as physicians, lawyers, engineers, statesmen, clerics and scholars who through superior intelligence and training will guide the destinies of the nation as the graduates of Oxford and Cambridge are reputed to have done for England for many years. We probably do need a small number of such institutions and no doubt this need will be fully supplied by the large privately-endowed institutions that tend steadily to raise their educational standards. But it should be remembered that their prototypes, Oxford and Cambridge, were developed to serve a handicraft age and their functions have been confined largely to the development of men who were to serve their country as statesmen, churchmen or as "rulers of subject nations." The newer universities of England are molded on a different pattern and more in accord with the needs of a new industrial era. On the other hand, there are those in this country who while acknowledging the need of a few superior institutions, recognize the very broad significance of engineering thought and methods that have been alluded to; and while recognizing also the necessity for high standards of education for all professions where protection of the public against charlatanism is concerned believe that state regulation and licensing should not be carried beyond the point necessary for such protection. This group holds that state regulation and licensing should not be used as a means of creating guilds or privileged groups beyond the point dictated by this need of protection. They believe, furthermore, that every individual is entitled to as much education as his ability will warrant and the public purse can afford, advocating that in a democracy it is just as important to raise the entire educational level as it is to elevate a few talented leaders.

If then the tendency of licensing boards and consolidated engineering groups should be toward the narrowing of the curricula

and toward the preparation of professional licensed engineers, only, the writer believes that the colleges should resist vigorously any such attempt. In the past the colleges of engineering in this country have resisted successfully and I believe wisely any domination of the curriculum by special industrial interests or narrow alumni opinion. As has been noted, the colleges of engineering in this country are concerned with a very wide range of service. And furtherfore, this field of service tends to expand not in the direction of refined specialization, but rather toward the economic and managerial side of industrial life. The importance of engineering methods grows steadily in the entire industrial fabric. In the nature of things the colleges will be called upon to prepare a decreasing percentage of highly trained specialists and an increasing proportion of engineering industrialists. The tendency is not unlike that now so evident in secondary education. A comparatively few years ago the primary function of the high school was admittedly to prepare students for college. This is still the primary function of private preparatory schools but the high school has relegated this function to the background and is concerning itself more and more with the large group of students that are not seeking college careers. In a similar manner registration and licensing of engineers and admission to the professional societies are sure to be of interest to a comparatively small group of graduates unless licensing regulations are extended to an unbelievable degree through the guild ideas which are essentially akin to trade union notions.

In any case it behooves the engineering colleges to study most carefully not only these movements, but also, as in times past, to take constant and careful inventories of all trends in engineering and industry for herein most surely constant vigilance is the price of liberty. And while fullest coöperation should be given to all good movements that will in any way elevate and enhance the reputation of engineers and engineering the faculties of engineering colleges should remain masters of their own destinies for they, and they alone, are competent to examine and appraise industrial and engineering trends and steer a safe and sane course thereby. This, furthermore, is no idle boast for the record of college trained men in this country needs no defense or justification. American engineering and American industry is basically the result of the work of engineering graduates and if the financial and business side of American industry has been anywhere near as efficiently conducted we would not be in the desperate straits we now find ourselves.

PROGRESS REPORT ON GRADUATE STUDY *

Your committee appointed to consider the matter of graduate work in engineering schools reports as follows. This report should be considered as preliminary and exploratory, only. Obviously, the field of graduate work is a wide and varied one and one that has grown up in the several institutions with little common guidance. For this reason your committee has selected a few salient features of this problem in an endeavor to find out whether a more comprehensive survey is desirable. If it should appear to the Council that such an extended survey is desirable, your committee recommends that funds be sought to make a thorough study of this problem either by a committee of the Society or by a paid investigator as may appear to the Council to be advisable. The report herewith submitted is based on the subreports by the several members of the committee. Since these members are scattered all over the United States, the report represents a sort of cross section of opinion, though naturally a very incomplete one. It is hoped, however, that it may develop some helpful discussion of this problem.

The Nature of Graduate Study.—It is believed that any discussion of graduate study will be more fruitful if some agreement can be reached as to the basic nature of graduate study, for in the opinion of your committee there is or should be a decided difference between undergraduate and graduate study. Undergraduate work on the part of the teacher is of the nature of *instruction*, and on the part of the student largely of the nature of acquiring as wide a knowledge of the field in which he works as time and ability will permit. For the most part both teacher and student are dealing with knowledge and facts already existent.

Graduate study, on the other hand, should be primarily of the nature of research. On the part of the teacher it should consist of *guidance* and on the part of the student it should be partially, at least, a venture into the unknown. No graduate work worthy of the name can be conducted solely by class room methods, so far at least, as the major study is concerned. None but students with initiative should undertake graduate work; but with this initiative there must be complete mastery of the necessary fundamentals. Before research of any kind is attempted a foundation of essential knowledge must be laid.

Graduate work may or may not involve actual work with

* Presented at the 40th annual meeting, S. P. E. E., Corvallis, Oregon, June 29–July 1, 1932.

machines or apparatus, and where machinery and apparatus are employed it should be for the purpose of developing new truths and should never be of the nature of simple testing of existing machines as is sometimes the case. The difference between real research work and commercial testing of apparatus is still not very clearly defined in many laboratories. In a number of institutions the master's degree is awarded for what really amounts to an additional year of course work, the student doing little or no original work. While no doubt course work may serve admirably for minor subjects, it would appear that no degree beyond the baccalaureate should be awarded without some evidence on the part of the student of ability to do original work.

Graduate work grows naturally out of undergraduate instruction and should have its roots therein and every progressive teacher should do advanced work of some kind in his field. It is true that many good teachers are not research minded, but it is also true that the man who is solely a good teacher tends to fall behind the progress of his specialty as he grows older. On the other hand, brilliant research men are sometimes very poor teachers. The combination of a great teacher and great research leader constitutes the ideal combination. Furthermore, since graduate work is essentially individual in character, there should be the greatest freedom of choice both on the part of the student and of the teacher. The student should be free to select his own field and his faculty adviser and the professor should be equally free to accept or reject any applicant for his services. In this it is assumed that the student is mature enough to choose wisely and that none but those competent to direct graduate work are permitted to do so.

Organization.—In a large number of American universities the general supervision of graduate work is entrusted to a special faculty consisting, most usually, of those members of the general faculty who are directing graduate work. There is usually a dean at the head of this faculty with adequate clerical assistance. Some such an organization follows naturally from the difference in character between undergraduate work and graduate work. Where the faculty is large some form of administrative committee is usually formed as an advisory body for the dean. The dean with the coöperation of this advisory committee conducts the details of his office such as admission of students, assigning of fellowships, making recommendations for degrees and such routine matters as naturally fall to his office.

Several methods appear to be in use for forming the administrative committee. Where the graduate faculty is small and the fields of work not widely diversified it may be satisfactory to elect such a committee directly from the graduate faculty. But in a

large university where there are many lines of work of great diversity of character it is essential that so far as possible the principal divisions of the university, at least, should be represented on the administrative committee. Perhaps the most logical manner of subdividing the faculty for purposes of this kind is to recognize the interest that the several divisions of the university may have in the graduate degrees. It should be remembered that while the graduate faculty is an excellent device for coördinating graduate work and caring for administrative details, it does not possess an undivided interest in the graduate degrees. A college of engineering, for instance, which is part of a large university has a deep and vested interest in all engineering degrees, since in the opinion of the public it is the college of engineering and not the graduate faculty that is held responsible for the quality of graduate work and the value of the engineering degrees both undergraduate, and graduate. If, therefore, the basis of election to the graduate faculty council is by a subdivision of the graduate faculty according to the *interest in the degrees conferred,* a fair and intelligent cross-section of faculty opinion should result. Such a plan virtually recognizes departmental or divisional faculties that would have a special interest in definite fields of work and which should result in greater and continued interest in the graduate work in each group. Regular meetings of such divisional groups can do much to stimulate interest in graduate study and research work. Whatever the organization, care should be taken that it is not over elaborate and cumbersome. There would appear to be less need of administrative machinery in graduate work than in undergraduate work.

Relation between the Dean of the Administrative Committee and Divisional Groups.—In many institutions the Dean of the graduate school with the aid of the administrative committee passes upon the applications for admission, and advises the student as to the faculty members under whom he is to study. Where the faculty is comparatively small, and in the case of polytechnic institutes where the fields of study are not markedly divergent, this may make a satisfactory arrangement. But in large institutions with many and divergent fields of study it is difficult, if not impossible, for any dean or council to administer successfully such a complex problem without the aid and advice of the colleges and divisions concerned. Only the faculty of a professional college or division can set the standards for advanced study in the field, and its opinions should prevail in regard to entrance requirements. Where such is not the case, men of inferior preparation will be admitted, due to the desire to have a large number of graduate students, thus lowering the value of the degrees and loading the

faculty with undesirable students. While, therefore, the dean's office is an excellent device for centralizing the admission of graduate students the criteria of admission should be fixed by the colleges and divisions affected. Similarly, a department head or a faculty advisory group in each college or division is most effective in advising students as to special studies and faculty advisers, the student usually being allowed much freedom in his choice of subject and faculty adviser.

There are cases, however, where the Dean's office may be of great service especially in the matter of comprehensive projects that involve more than one department. In fact, it would appear to be a part of the Dean's functions to spy out and develop large scale projects and to build up coöperative efforts for their prosecution, thus obviating duplication of effort and useless expenditure of funds.

On the question of checking up on the students progress procedure appears to be divided. Where work is conducted by class room methods periodical progress reports can be used and in some instances are forwarded to the central office. Where the work is of a research nature, this practice is not so commmon and perhaps for obvious reasons. After all, there is little that the dean or central commmittee can do about such matters and full dependence must be placed upon the faculty members who are directing the work. It would appear that the most satisfactory relation that can exist between the central committee and any large number of educational divisions, so far at least as the masters degree is concerned, is to depend upon the central committee for the general administration of admission requirements and of all matters pertaining to the general welfare of the graduate work, but to depend upon the divisional groups to guard the quality of the work in that group, the central committee reserving the right to send observers into any examinations that may be conducted by any group. This practice of depending mainly upon the divisions for the actual administration of the requirements for the master's degree appears to be quite common.

In practically all cases the work for the doctor's degree is not delegated to the divisions, but is supervised more or less directly by the graduate committee through the office of the dean. The question has been raised as to whether the examination could and should be conducted by representatives of the general graduate committee rather than by those that direct the work. The point appears to be worth considering as practice appears to vary.

In some institutions primary dependence is placed upon the candidate's guiding committee for the examination with the graduate school reserving the right to send representatives to the exam-

ination. In other cases, the examination is conducted by others who have had no part in the guidance of the candidate with representatives from this last group in attendance at the examination.

Requirements for Graduate Study.—Engineering colleges in general require the satisfaction of all requirements for their baccalaureate degree for admission to graduate work. In some instances the quality of the applicant's undergraduate work is, also, carefully scanned just as the record of high school students are examined for entrance into the college. This practice is to be commended for it does, no doubt, eliminate some of those who are not capable of real advanced study. It has been suggested that all prospective graduate students be required to present a clear statement of his objectives before registration for no doubt some graduate students have very vague ideas as to their program. There is a wide variation as to language requirements both at entrance into the graduate school, and as a requirement for graduation therefrom as might be expected from the variation in language requirements for entrance to undergraduate work. In some institutions the requirement of foreign language is optional so far as the master's degree is concerned, while all apparently require at least a reading knowledge of one or two foreign languages for the doctorate. This matter has already been given considerable general study, but it may be desirable to restudy it with special reference to graduate work in engineering.

All institutions apparently require one year of study for the master's degree and three for the doctorate. The rules governing actual residence vary somewhat, but in general full residence must be fulfilled either at the institution conferring the degree, or by partial residence elsewhere. As has been noted, the methods of conducting graduate work vary somewhat. In most instances, a student must select a major subject and one or more minor subjects for the doctor's degree. In practically all institutions the candidate must present a thesis on his major subject for the doctor's degree, and considerable stress is laid upon the thesis and the final examination which is usually oral in character, and often covers both major and minor fields. But the practice as concerns class room and lecture work as a means of satisfying either major or minor studies, as has been stated, varies widely. Some institutions offer a larger number of graduate courses, so called, while others, while permitting the satisfaction of minor subjects by course work, demand original work for the major subject and the thesis. It would appear that some constructive thinking and a more uniform understanding could be developed in this direction.

Degrees.—There is perhaps a wider range of opinion and practice in the matter of advanced degrees than in any phase of this

work. The following are awarded for the master's degree in different institutions.

(1) M.S.
(2) M.S. with connotation thus, M.S. in M.E.
(3) M.C.E., M.M.E., etc.

For the doctor's degree the awards are

(1) Dr. Sc. or Sc.D.
(2) Dr. Sc. with connotation thus, Dr. Sc. in E.E.
(3) Dr. Eng.
(4) Ph.D.
(5) Ph.D. with connotation thus, Ph.D. in E.E.

There appears to be considerable sentiment for the use of the degree of Doctor of Philosophy for the doctorate in engineering in spite of its humanistic origin. Also, there is little support apparently for purely honorary degrees, though there is a practice in some institutions of awarding the professional degree to graduates who have done meritorious work in practical work. It would appear that some constructive work could be done upon this phase of graduate work.

Graduate Professorships.—The question has been raised as to whether in any faculty engaged in undergraduate instruction certain individuals should be set apart to devote all of their time to research and to the direction of graduate work, while the remainder of the faculty devote their energies to teaching undergraduate work and offering such courses as might be accepted for minor subjects. No doubt it is often justifiable to assign certain professors entirely to research, but whether any group of men should be given sole direction of graduate work is an open question. Such a plan may save the student from falling under indifferent guidance, but it would appear on the whole as though all full professors should be competent and eligible to direct graduate work. One of the tragedies of academic life is the teacher who ceases to grow and develop, and the direction of graduate work certainly does help to keep the professor who does such directional work alive and progressive. Yet it is common observation that many good teachers are not competent to conduct research work and graduate study. A discussion of the qualities needed by a professor successfully to conduct graduate work might be helpful. It certainly is a problem in many places.

Coöperative Graduate Work.—In recent years a few universities advantageously situated have engaged in coöperative graduate study with commercial institutions that have interest in such work and both personnel and facilities that make good work of this kind possible. There would appear to be no good reason why such work cannot be successfully conducted and your committee recommends

that any comprehensive study that may be inaugurated includes this development within its scope. The interest that many large commercial enterprises are manifesting in advanced engineering study appears to be more than a mere selfish one and at any rate the problem is worthy of discussion.

Cost of Graduate Instruction.—Graduate instruction is very costly and often lays a heavy load on the older and more experienced members of the staff. It is customary in some institutions to ask a much lower fee for graduate work than for the undergraduate work, usually on the ground that graduates are more often mature persons of limited means and without parental support. The tendency, however, in recent years in privately endowed colleges is to allow no such differential. The arguments pro and con on this point have never been fully presented.

Respectfully submitted,

KARL T. COMPTON,
M. S. KETCHUM,
P. R. KOLBE,
A. S. LANGSDORF,
C. E. MAGNUSSON,
E. B. ROBERTS,
R. W. SORENSEN,
G. B. THOMAS,
ALFRED H. WHITE,
DEXTER S. KIMBALL, *Chairman.*

APPENDIX

As a further indication of the general character that a study of graduate work might assume there is appended an outline submitted by President P. R. Kolbe of the Brooklyn Polytechnic Institute where this problem had been under discussion for some time preceding the initiation of this report. It raises so many interesting questions that your committee believes it may help to present a tentative program in a very concise form.

Suggestions for a Study of Graduate Work in Engineering in the United States

I. *The Basic Nature of Graduate Study* (Collect Opinions)
   1. The place of pure science.
   2. The place of applied science.

II. *Administration*
   1. Relation to institutional organization.
   2. Body (Faculty, Committee) in charge.
   3. Administrator directly in charge.
   4. Departmental organization.

III. *Faculty* (Concerning those in charge of graduate study)

1. Rank.
2. Preparation and teaching experience.
3. Degrees held.
4. Industrial contacts and experience.
5. Teaching load.
6. Relation of graduate to undergraduate teaching load.
7. Is special remuneration allowed?
8. What proportion of faculty engages in graduate teaching?
9. Visiting professors—research professors—graduate professors.

IV. *Requirements for Admission*

1. Are all college graduates admitted?
2. If not, what additional quality or subject requirements are imposed?
3. Are preliminary examinations given?
4. Are undergraduate students admitted to graduate courses?
5. If so, under what restrictions?
6. Are special students or auditors admitted?
7. When and how may a graduate student be accepted for candidacy for a degree?

V. *Nature of the Course*

1. Proportion of required class, laboratory or seminar courses
   a. for the master's degree,
   b. for the doctor's degree.
2. Proportion of independent research required
   a. for the master's degree,
   b. for the doctor's degree.
3. Arrangements for faculty contacts (Advice, guidance, supervision).
4. Proportion of required majors and minors.
5. Required non-scientific subjects—nature and proportion.
6. Minimum time required for master's and doctor's degrees.
7. The coöperative plan in graduate study.
8. Credit for courses in industrial laboratories.
9. Other contacts with industry.
10. Graduate work in Evening Sessions.

VI. *Graduate Fellowships*
1. How many available?
2. Stipends.
3. Services requirements.

VII. *Library*
1. Size.
2. Status of basic reference works—journals.
3. Availability to graduate students.
4. Staff.
5. Annual appropriations.

VIII. *Laboratories and Equipment*
1. Are adequate special research laboratories available?
2. Is scientific apparatus and equipment adequate?

IX. *Thesis*
1. How determined.
2. Time allowed.
3. Credit given.
4. Relation to institutional or departmental research program.
5. Methods of guidance.

X. *Examinations*
1. Examinations in course.
2. Final examinations.

XI. *Degrees*
Historical study of degree practice and degrees already given.

XII. *Costs*
1. How budgeted?
2. Fees charged students.
3. Can student costs be estimated?

XIII. Conditions surrounding Graduate Work in foreign universities and technical schools.

REPORT OF CONFERENCE ON RESEARCH

A conference on research, sponsored by the S. P. E. E. Committee on Engineering Research, was held at the Oregon State College Wednesday morning, July 29, 1932, in connection with the annual meeting of the Society. Dean R. A. Seaton of the Kansas State College, chairman of the committee, presided.

Dean Seaton reported that the committee had worked during the year on three principal projects:

1. Collection of information on the progress of engineering research in the colleges and universities of North America, to bring to date the report printed in the Supplement to the February, 1931, JOURNAL. Reports had been received from nearly all of the institutions, and were being prepared for publication.

2. Collection of additional suggestions from industrial research workers as to subjects suitable for research work in educational institutions, to supplement the report published in the Supplement to the February, 1931, JOURNAL. Many interesting suggestions had been received and were nearly ready for publication.

3. The Conference on Engineering Research.

The following papers were presented at the conference:

RESEARCH PEAKS IN THE VALLEYS OF INDUSTRIAL DEPRESSION *

BY MAURICE HOLLAND, *Director*

Division of Engineering and Industrial Research, National Research Council

Rising above the fog of depression and the gloom of despair, which has settled in the Industrial Valleys there are the Peaks of Research. In the Research Range there are Mount Industry, Trade Association and University Peaks. The Peaks of Research have risen in the last two years like rocks above the industrial waters at low tide. Where the tide of Industry has reached its lowest ebb the Peaks of Research have risen proportionately. Industrial executives have been desperately clinging to Peaks of Research, anchored in the bed rock of science. Research offered a solid foothold in the swift tide of industrial competition. Some leaders of industry, however, fear that even research must follow the trend

* Presented at the 40th annual meeting, S. P. E. E., Corvallis, Oregon, June 29–July 1, 1932.

of the main current. Some cuts in research staff and appropriations have been announced recently. Research may suffer even more in the next few months when the accumulated effects of the long continued depression in general industrial activities may dictate further reductions. This is the back drop of the research picture.

Most significant of all the mountains in the Range of Research is the University Peak. Industrial laboratories are turning more and more to the universities for research assistance, particularly in fundamental investigations looking towards basic improvements in industrial technology.

At no period since the World War has industrial research been put to the acid test as at the present time. Will executives consider research as overhead? Will research appropriations suffer the same reductions as advertising and sales promotion? Or will these enlightened executives turn to research as the most promising field for the development of new products or old products in new packages, in an effort to recover some of the lost business?

To secure some factual data on this subject a so-called "depression" survey of research activities has recently been completed by the Division of Engineering and Industrial Research. Questionnaires were sent to the 1,600 industrial research laboratories listed in an official bulletin of the National Research Council. The survey was designed to bring out how research is being used as an aid to industry during this period of subnormal business. An effort was also made to determine just how the depression was affecting research activities in three major fields: Private industrial research laboratories, trade association, and university research.

From 500 letters received and analyzed there appears to be less depression in the research industry in proportion to general industrial activities (although it is conceded that this might change during the next 12-month period). Research is being translated into new products, more employment, new industries, and better business. Out there on the frontiers of American industry, 30,000 scientists are busy laying the foundation for future depression-proof industries. Recent discoveries of these "industrial explorers" are bringing new life to sick industries.

Quick frozen foods (an industry born in a test tube) is putting men to work and meeting the hunger for new needs. Glass bricks arrived the other day. Science steps into the kitchen and provides knives of stainless steel, vacuum cooking and ice cubes. Factories are making floor coverings from corn stalks, peanut shells or rice hulls. Modern magicians have introduced a new industry of nutrition, light weight cement using magnesia, and plastics as substitutes for wood.

In 50 per cent. of the companies reporting, more dollars were spent on research in 1931 than in the boom year of 1929. Building material companies are using more sales income for research than ever before. Nine-tenths of them are marketing new laboratory products developed in the last two years. Research has cut production costs, retained consumer good-will, and developed a host of new products during the depression. New building methods, new types of structures, 24-hour cement are around the "science corner" in the building industry. 71 per cent of the reporting companies are spending as much as they did in 1929. 74 per cent of the reporting companies are spending a larger proportion of their sales income on research than they did in 1929, while 93 per cent have made no decrease.

This would indicate that in the judgment of executives of a large majority of the reporting companies research as a major tool of industry is growing in importance and usefulness compared with other tools at their command.

In the opinion of a majority of the directors of research of the reporting companies, their industries will be largely affected by future technical developments. Less than one-tenth of them have felt that future technical developments would have no serious affect on their companies. Three-fourths of the companies gave definite answers to the question of future technical developments, indicating a very wide range of possibilities, including new products from hydrogenation of oils, new types of internal combustion engines, stainless castings, thermionic devices, replacement of castings by welded steel, new types of tires and increased industrial uses of vacuum tubes.

The machinery industry reflects the settled policy of a conservative industry. Only one-fourth of the companies decreased their research expenditures in dollars. That they are alive to the possibilities of technical improvements is shown by 41 per cent of the companies increasing research expenditures. This is significant as the machinery industry serves most other industries. It is therefore geared directly to efforts to increase general industrial efficiency.

"*Research as an aid in combating industrial depression*" was listed under 8 specific headings and based on concrete evidence that production costs had been reduced, products improved, new products developed, profits from by-products, maintenance of customer's good will, sales aids developed by research, development of profitable specialties, and diversification of products.

Of the 1931 research dollar 42 per cent of the companies devoted their major emphasis on the development of new products; 37 per cent on improvement of present products and services;

13 per cent on reduction of production costs; 6 per cent on the development of new fields of application; and only 2 per cent on the development of by-products.

Five hundred industrial companies answered the questionnaire during the period of the survey from March 1 to June 1, 1932. The figures quoted above are based on an analysis of these data, as a representative cross-section of national industrial research activity. During this period the continued decline of business activity and the accumulated effects of the depression have made necessary some reduction of research appropriations and activities.

What is the position of university research in the general research organization? During the last few years industrial research laboratories have been turning to universities, particularly for fundamental investigation and for the purpose of cross-fertilization with their own research staff. University research is in the foreground of the research picture today.

"The university laboratory as a partner of industry" has been described by Dugald C. Jackson in a chapter of "Profitable Practice in Industrial Research" published recently by Harper and Brothers under the auspices of the Division of Engineering and Industrial Research of the National Research Council.

I quote a few of the statements made by Professor D. C. Jackson, Past President of this Society:

"The universities, including therewith the engineering schools, are the reservoirs on which practical industry must rely for its supply of young men to become its research workers, its scientific designers, and its wisest executives. From their research side, the universities and engineering schools are proving themselves practical-minded enough to see industry's research needs and to become active partners in the effort to satisfy them through collaborative effort. If we may assume that the first of these purposes—the training of workers—needs no further argumentative support here, we may proceed to the subject of collaboration between the schools and industry in research projects."

"The spirit of inquiry needs for its complete fertilization ample provision of unrestricted time, and proper facilities for reflection and for the conduct of experiments. Such opportunities are not always to be found in the research departments of industrial corporations, where the primary object of industry shifts the pressure to the side of immediate practical results rather than the pursuit of fundamental knowledge. To increase this latter invaluable asset we must turn—theoretically at least—to the research laboratories of American universities and engineering schools, and the few other laboratories established and sustained with independent motives."

"There is scarcely an important and flourishing industry in existence today which has not been aided by the results of studies and researches of university faculties."

"The fruitfulness of the men and laboratories associated with universities and foundations in making discoveries which are deeply influencing the industries has been so amply demonstrated that the large American industrial companies which can afford to maintain great research groups for themselves also serviceably maintain relations with the established educational institutions and research foundations. Progress in the smaller industrial establishments largely depends upon results secured from some special type of group effort, such as may be secured in the university laboratories."

"Industry will find it increasingly profitable to become interested in, and to aid by contributions of counsel and money, research in universities and institutes where such work is being successfully carried on under the hands of adequate men. Selectivity and discrimination, in the sense of recognition of experience and fitness, are necessary to avoid waste of money and effort in coöperative relations which grow up between the industries and the engineering schools; and the institutions should aim to make their efforts at industrial coöperation primarily with those industries which have establishments within nearby territory, and whose interests lie principally within the range of each institution's individual equipment and curricula. Such coöperation and support need not, and should not, interfere with educational autonomy of laboratories nor abate the independent resourcefulness which it is desired to cultivate in the laboratory employees and students. If an intermediary or clearing house should prove to be needed to vitalize particular coöperative contacts, the National Research Council or some similar body can serve as an impartial agency to perform the function for the mutual advantage of the educational institutions and the industry concerned."

Other addresses presented at this meeting will cover several aspects of this subject. My own contribution is to bring you some evidence of the attitude of industry, particularly the directors of industrial research, toward the utilization of university research facilities.

The attitude of industry in some measure is dependent upon the attitude or experience of their directors of research. In other cases the attitude of the management as well as the heads of different universities is the controlling factor.

At the present time many branches of industry find their progress limited or handicapped either by a lack of fundamental information or a supply of suitably trained men. It is not surprising therefore that the degree of coöperation of industry with university is dependent on the measure in which one or both of these needs can be supplied. The problem of coöperation between university and industry has engaged the attention of leading industrialists and educationalists for a number of years. A number of excellent papers have been written on this subject including that of Pro-

fessor Jackson referred to above. You may be interested in a few specific examples which might furnish data for general deductions.

The industrial utilization of the research facilities of the university may be roughly divided into three main groups:

1. Trade associations.
2. Technical societies.
3. Companies and individuals.

Trade Association and the University

Perhaps the most satisfactory arrangements in regard to university research can be made by the trade associations. As a rule the trade association has no objection to the publication of the results of research as quickly and as widely as possible. It is generally feasible for them to make suitable financial arrangements. Moreover, the heads of universities are in general more favorably disposed in entering agreements with trade associations and technical societies than they are with individuals or companies. Three associations were selected for a study by the Division representing three different industries: namely, food, certain branches of the chemical industry, and public utilities. A digest of the replies received emphasize these points.

The selection of the university is largely dependent on the fitness of the personnel, the facilities of the laboratory, and the attitude of the heads of the university. Generally a man is selected who has had previous experience in the field. One of these trade associations spends nearly $100,000 annually for the maintenance of fellowships. This association also finances several projects of major importance at representative universities.

The trade association examined in the food industry finances investigations at some twelve universities. This association reports that their individual financial arrangements vary. In some cases they have found arrangements satisfactory and in other cases not so satisfactory. They point out that in many instances when the money has been transferred to the university there is a loss of interest. In some cases when the work is completed it is difficult to obtain publication of the results. In spite of this they believe in university research fellowships because the results are generally accepted as authentic and free from commercial bias.

The public utility association, while utilizing the resources of some half dozen universities, finds that the university is quite effective in carrying through a specific project after that project has been thoroughly analyzed by their research committee and proper objectives set up. They do not regard the university as specially fitted to carry through ideas to the commercial stage.

Recognizing the importance of fellowships and scholarships in scientific research pertaining to the textile industries in the fields of chemistry, physics, and biology the Textile Research Foundation has recently decided to award 24 fellowships and scholarships. The broad purpose of this far-reaching program is to build up and develop a body of research trained individuals. Although engaged in scientific fields the research workers will at the same time be working and thinking in terms of textile fibre and material development.

Technical Society Activities

In general the same principles governing trade association research in universities are applicable to research conducted for technical and engineering societies. There is one major difference, however, namely, that a technical society finds it generally more difficult to finance investigations. Their investigations are more apt to lean towards fundamental research and include less of the so-called "development research."

As an illustration of research in this field, a project of the American Bureau of Welding which is sponsored jointly by the American Welding Society and the Division of Engineering and Industrial Research of the National Research Council will serve our purpose. The Bureau has sponsored both practical and fundamental investigations. A great deal of practical work was conducted at university laboratories and also at the Bureau of Standards. These investigations are being carried out in the various universities in the country. 33 projects are listed. The Bureau of Welding compiles each year a list of fundamental research problems. The list of problems is distributed to the various universities. The Bureau also assists in the formulation of projects undertaken for study, the preparation of bibliographies, and in supplying specimens and materials as may be required and specified by the university laboratories. It also assists in supplying special apparatus and assistance as may be needed from time to time. Once a year the university workers are brought together for conference for which the Bureau provides traveling expense.

Individual Companies vs. the University

As examples of private industrial research in universities three companies have been selected: two from the food industries and one from the pharmaceutical field. Take the case of the pharmaceutical company: In one large medical project 10 universities cooperated. On another investigation involving arsenical research, 4 fellowships are maintained at one university and 1 other at a second university. Smaller coöperative research projects are being

conducted at a number of others. This company states that the cooperative arrangements are more for the immediate benefit of the research worker than for their own. They realize that ultimately the field of medicinal products will benefit. This company supports research projects at 50 universities and colleges.

One of the food companies mentioned maintains two fellowships at one university and one each at 10 others. This company states that they are especially interested in the promotion of better technical education. In many instances a problem arises which is difficult to finance because the results achieved cannot be adopted commercially. This company prefers to make a small expenditure of money at a university where research is being followed. The company can then avail itself of the training and experience of experts in the field. This company also is very much interested in the training of men. It does not believe in judging the research produced at the university on a purely financial status. They feel they have a sufficiently broad knowledge of the subject and are able to promote developments in unexpected ways. Furthermore this plan permits them to have a larger vision of the possibilities in the field. They state that perhaps 10 years or more after the discovery of a scientific fact, commercial application can be made.

Summary Compliments and Complaints of University Research by Representative Industrial Executives in Charge of Research

Compliments

We have found university research quite effective in carrying through a specific project after the project has been thoroughly analyzed by our research committee and proper objectives set up.

There is a tremendous prestige value in having certain data originate and verified by and in properly equipped university laboratories.

The results are accepted by nutritionists and other professional people as being unbiased. We believe all the grief and expense we go through in seeing these things through is recompensed by the effectiveness of the results when and if finally turned out.

In many instances a problem arises which it is difficult to finance because the results achieved might not be such that they could be adopted commercially. Often a small expenditure of money at a university where pure research is being followed is more satisfactory and furthermore it gives one an opportunity to avail oneself of the training and experience of an expert in the field.

We have found university research of value in our general research program when the facilities of the university, either in personnel or experience have made it particularly adaptable for solving a given problem.

Complaints

In general the university results come much slower than from our own force or from consulting laboratories. Problems assigned to universities are not of a more pressing nature.

So many times when the money has been transferred from our treasury to that of the university there is considerably less interest manifested than there was before. It has most always been very difficult to even get a letter once in two or three months as to what is being done and accomplished. In many cases when the work was completed it has been difficult to obtain publication of the results. In practically all cases the progress has been very slow. Some of the research projects started three or four years ago have not yet been completed and published.

Survey of University Research Facilities Needed

While several reports and surveys of the physical research facilities have been made, notably the report of Dean Seaton, the growing demands of industrial research executives require an extensive survey on a national scale of all university and college research facilities. The survey I have in mind would do more than list laboratory facilities and physical equipment. It would develop yardsticks which attempt to evaluate the research experience and achievements of the personnel and the attitude of the heads of these universities toward research.

About a year ago the Division appointed a committee on Bridging the Gap Between the University and Industry, with Dean Barker as its Chairman. This committee's membership represents 15 or more universities and colleges which have had some considerable experience in industrial research. The committee has had two meetings to consider ways and means of conducting the survey, formulation of a program and assurance of the necessary financial support. The committee has had the benefit of the advice of representative research executives from industry. Dean Barker will report progress at other sessions of this meeting.

The interest of the Division in this important project is to canvass the university research situation thoroughly and through its committee make these data available to industry generally. The findings of the committee reporting through the National Research Council will be accepted by industry as unbiased. The results of the survey should stimulate research in universities generally and a wider and more diversified use of university research by industry. Finally this effort will relieve the universities and colleges, at least to some extent, of the necessity of taking aggressive and openly competitive measures to secure their share of research projects and support from industry. Therefore I bring to you personally on

behalf of the Chairman and Executive Committee of our Division the earnest request for your active coöperation with Dean Barker's committee in the important work of our mutual interest. I should like to go further in submitting to this meeting the suggestion that each university and college represented here send in to Dean Barker any comments and suggestions and consider the appointment of one member of the faculty who would take the responsibility of serving as the active coöperative in the work of Dean Barker's committee at their respective institutions.

University Research Survey to Complete the Picture

In the larger aspect of our Division operations of promoting research a complete survey of university research resources is absolutely essential to round out the national survey of research which has occupied an important position in our program during the last three years. During that time we have completed surveys of industrial research laboratories in the boom year of 1929 and the second year of the depression, 1931. We have also made an extensive survey of trade association research activities as reported in a chapter under that title in "Profitable Practice in Industrial Research" by Secretary Spraragen. University research is the fourth cornerstone and the national foundation of research, the other three being represented by Government, trade association, and private industry research activities.

In the trying days to come, of more highly intense industrial competition in which science will be the new business strategy, this foundation will need to be anchored in the bed rock of science. The biggest opportunity for university research lies ahead.

Finally the resources and facilities of the Division and its staff backed by ten years of experience in research is yours to command. Our principal service to industry is to act as adviser in placing research in the agency best suited to a specific project and particularly in these times of rigid economy, where the largest return of the research dollar may be expected.

INCREASING IMPORTANCE OF RESEARCH IN ENGINEERING EDUCATION

By C. EDWARD MAGNUSSON,

Director Engineering Experiment Station, University of Washington

In opening this round table discussion let me direct your attention primarily to the importance of research as a factor in the training of graduate students in our engineering colleges and technical schools; to the upper brackets in our engineering curricula,

where important advances must be made to meet properly obligations imposed by the new economic order.

It will be admitted without argument that the length of the training period necessary for entering a profession, whether it be engineering, law or medicine, has an economic basis. Necessarily many factors of widely varying importance enter into the equation for the economic balance, but for the purpose of this discussion a summation of the effects may be found in the law of supply and demand as applied to graduates seeking professional employment.

In the overcrowded professions of Law and Medicine the length of the training period has, for the past thirty years, steadily increased and, by now, the curricula in our leading colleges of Medicine or Law require at least seven, in some medical schools nine, years of collegiate study subsequent to graduation from high school, for admission to professional practice. In the Engineering profession conditions have been markedly different in the United States, in that the length of the training period has remained essentially constant; that is, four or at best five years of collegiate study after graduation from high school. The main cause for this marked difference is found in the unparalleled growth and development of our industries which created a corresponding increase in the demand for engineering graduates, with comparatively little effect on the professions of Medicine and Law. In the decade following the War, the hey-day of our industrial expansion, the demand for technology graduates exceeded the available supply. All engineering graduates readily found employment and the larger and more progressive industrial organizations were bidding for the more promising students; offering special inducements to enter their employ, as splendid opportunities for graduate study to be followed by rapid professional advancement. But the tide suddenly turned in '29 and the business waters are still receding. No representatives from large industrial organizations have traveled cross country this year to interview seniors and to offer employment directly after graduation. The "starvation period" which has long been recognized as the inevitable first stage in the professional careers of young doctors and lawyers now confronts engineering graduates as well.

However, industrial stagnation cannot endure for long and in attempting to forecast future events it appears quite likely that engineers are as well qualified to make assumptions and to express opinions as economists or financiers. As premises in the discussion let it be assumed:

(*a*) That the tide of industrial activity is by now at extreme low ebb;

(*b*) That in the near future stable business conditions will be realized, presumably on a new economic level;

(*c*) That industrial recovery will be slow, probably very slow, extending over many years.

No change will be necessary or even desirable in entrance requirements or in the curricula for the freshman, sophomore and junior years. Even the number of entering freshmen will probably not be affected. This year's decrease in freshman enrollment will probably prove to be merely a dip in the curve and not a permanent feature. Probably the most important effect on undergraduate students will be that, due to a lack of outside employment, a larger percentage of the entering freshmen will complete their college course and graduate, than has been the case in past years.

However, it is after graduation that the conditions in the future will be vastly different from what engineering graduates met in the twenties. It is evident that this year, and probably for years to come, there will be many more four-year-curricula graduates available than can possibly find employment in any engineering field or even in fields more or less related to engineering. As a consequence, an increasing number of students will return for post-graduate work in the hope that better training, as evidenced by an advanced degree, will give them preference in securing desirable employment. On the same basis an increasing number of Masters will, sooner or later, become candidates for the Doctor's degree. That is, the competition for desirable positions will automatically increase the period of training for entering the engineering profession from the present four-year basis to five years and, in some cases, seven years duration. Or, if viewed from present conditions in other fields, it appears probable that in a not distant future the training represented by the Doctor's degree may become as necessary for professional engineers, as now obtains in the related fields of physics, chemistry and mathematics or in the professions of Medicine and Law.

This trend of extending the training period is markedly evident in continental Europe, particularly in Germany where economic conditions have been very severe, in that the doctor of engineering degree has become practically required for entrance to the engineering profession. Already this year, there has come to my office, from the Technische Hochschule in Berlin, printed copies of sixty-seven doctors' thesis, or as stated on each title page: "Dissertation zur Erlangung der Würde eines Doktor-Ingenieurs."

Necessarily, only a part of the four-year-graduates will return for the Master's and Doctor's degrees, but the percentage will be rapidly increasing. Moreover, the work for the advanced degrees may cover a wide range of subjects; as graduate courses not only

in all branches of engineering proper but also in economics, administration and management, in physics, chemistry and mathematics and a variety of other fields. However, although set courses, professorial lectures and seminars will require a large and important part of the student's time and effort, the prime characteristic of graduate work, particularly for the Doctor's degree, should be individual research. The development of initiative and attitude of mind necessary for solving new problems, the exploration of new fields and increasing the store of human knowledge, in short, research must ever be the prime objective of graduate study.

If it be admitted that under the probably new economic order the training period for admission to the engineering profession will be increased, so as to be more nearly in accord with the corresponding requirements for the professions of Law and Medicine; and, if it is likewwise agreed, that research forms the very core and essence of graduate study, then my thesis on the increasing importance of research in engineering education would be established.

However, the assumptions made as a basis for this discussion may not be valid. The present economic malheur may soon pass away and be forgotten. It is possible that the predictions of our optimistic captains of industry, that we are on the eve of a period of great and lasting prosperity and of unprecedented industrial activity, may be true. That the demand for engineering graduates will again exceed the available supply and that economic balance in engineering education will, in the main, be met by the present four-year curricula.

RELATIONSHIP OF ENGINEERING RESEARCH TO ENGINEERING EDUCATION

By ARTHUR N. TALBOT

University of Illinois

It is a matter of history that the pioneers in American engineering depended largely on ingenuity, experience, precedent, vision, and judgment. Their practice was based principally on their ability as skilled craftsmen, and they were ingenious in construction methods, resourceful in meeting emergencies, fertile in conception, and bold in execution. They applied their knowledge largely as an art with little information and scant consideration of what is now termed engineering science. The later years have brought, in increasingly large degree, through the development of research and of analytical and experimental investigation, a body of knowledge—applied science—engineering science—which as all

know has exerted a tremendous influence on the scope, methods, practices, values, and expansions in the whole engineering world. The youngest of the principal branches of the engineering profession (electrical engineering) was fortunate at the very beginning of its development in recognizing the vital need of analytical and experimental and scientific research upon the development and growth of the manufacture and transmission and utilization of electric power, and so research has always been a constituent element in its marvelous growth and development. On the other hand, the older branches of civil engineering and mechanical engineering lagged behind and were less appreciative of the value of engineering research. In recent years (particularly in the last 20 years) there has been an awakened appreciation of the value of research along all lines of engineering, with resulting value to the whole engineering profession. Research organizations, engineering societies, educational institutions, governmental agencies, private laboratories, and industrial plants have all contributed to engineering science.

This awakening to the value of research naturally has had a marked influence on the engineer and his work. In all directions new knowledge has appeared bearing on the principles and practices of the engineering profession. As an inevitable consequence the student in engineering schools and his instructor have been affected. It seems proper, then, that consideration be given to the relationship between engineering research and engineering education, including in its scope the engineering college, the engineering teacher and the engineering student.

Some Relations between Research and the Engineering College

Just as the university, in its capacity as a source of knowledge and an instrumentality for its dissemination, has for one of its great functions the vital function of adding to the world's store of knowledge, so it may be affirmed that an engineering college should not only disseminate learning but likewise be an active producer, a contributor, an instrumentality for searching out truth, for adding to the world's stock of engineering knowledge in applied science.

It seems evident that activity in this research function should result in the first place in improvement in quality of teaching, and any activity that improves instruction has value for a teaching institution. Always it must be kept in mind that teaching is the first and foremost function of a college or a university. It should be accepted of course that a good teacher may not be a a good research man. Still it will be evident, I think, that the presence in

the institution of research activities of various kinds and particularly participation in the conduct by teacher and student may be expected to add in various ways to values in engineering instruction. Especially in graduate work does the conduct of experimental and analytical research and participation therein give opportunities for higher educational values in ways that are stimulating and fruitful. For teacher and student and institution the presence of research then should give real advantages.

The advantages of research to the engineering teacher seem obvious, but for the sake of possible discussion the following will be mentioned:

(*a*) A general stimulus and an increased wide-awakeness is apparent in the presence of research and experimentation, whether participated in or not. It is always interesting to see how local discussions of the progress of the investigation and chances to appraise and criticise the methods and results stimulate the mind even of those not connected with the investigation. With this interest is likely to go an enlivening of the mental processes of the teacher in his own subject matter, helping to keep him out of the rut and even preventing him from becoming stale in his work.

(*b*) To the man who engages in the processes of research, the renewed mental activity, the investigational curiosity, awakened in the conduct of the investigation, unite in inducing freshness in manner of presentation and in adding life and vigor to instruction.

In thus speaking of research it hardly seems necessary to remark that I do not mean to minimize in any way the educational value and usefulness of instruction in the fundamentals of analysis and design and engineering practice.

The real teacher, who inspires and stimulates and educates, may not always need this contact—I want to give him highest credit—but even he may be benefited by contact with research.

The values of engineering research to students who are not participating in its conduct may further be indicated by these expressions: (*a*) a stimulating educational atmosphere; (*b*) improvement in quality of instruction; (*c*) the view that engineering is progressive and that the body of professional knowledge is in a state of evolution; (*d*) further, that since engineering science and engineering practice are in the state of constant change and growth the man who expects to keep up with the times through his professional life must continue to be a student and grow with the growth of his profession through the many world changes. Moreover, of direct benefit to him will be the study of the results of researches as sources of engineering knowledge and as affecting changing engineering practice either in the making or in prospect.

The values of college research to the student participating in the work are even more direct and immediate. Especially for the graduate student, the opportunity to be connected with engineering research in one way or another should give a stimulus, a new view-point, a better knowledge of basic facts and principles, and a realization of factors that enter into the establishment of the principles of engineering science. It may be said then that participation in research and a study of research methods and data constitute one of the most valuable opportunities in the pursuit of graduate study. As a means for educational development the conduct of research in engineering schools should be considered to hold high place.

May I be permitted to make the remark here that my high estimate of the value of research to student, teacher and institution has been formed and strengthened by more than 40 years of contact with it in an engineering school that has been growing and developing throughout that period.

The strongest reason for the conduct of engineering research by the engineering school is the intrinsic value of the products of research which may be contributed to engineering science and to the uses of the engineeering profession. The opportunities and advantages possessed by such institutions lie in the special facilities and equipment and personnel and surroundings inherent in the institutions themselves. In considering such advantages it will be well to consider the varieties of research problems and the many kinds of agencies that may carry on research work.

Kinds of Research Activities

Two classes of research activity may be named, (1) that privately conducted and having the product privately controlled and (2) that more publicly conducted and having the product generally freely usable by all. The first class has for its objective mainly financial gain, its results and its use restrained by patents or other forms of ownership, as in industrial processes and in details of manufacturing. Its main purpose perhaps may be called selfish and it may be actuated by the commercial instinct, though of course the utilization of the results may benefit the public and the by-products of the investigation may be given freely to the scientific world. Its propriety and its value are appreciated, and the further development of its activity is assured. Under proper restrictions even this form of research activity may be rightfully taken up by an educational institution.

The second class of research activity has a more direct connection with the general public and with individuals not connected with the research agency. For one thing the results may be useful in a professional way. To illustrate, the engineer or the architect

may utilize the principles, the methods, the scientific findings, to serve a client, who may be an individual, a corporation, a municipality. Naturally the client can not by himself spend the money and the time in an investigation to develop the knowledge needed in the design and construction. The engineer does not profit from the use of the information in a way that will warrant his maintaining the research activity, even though the new knowledge may give added prestige to his profession. This professional aspect of research is of the highest importance to the engineer, for the practice of engineering at the present day is based upon engineering science and this engineering science must be fed by research or the art of engineering will become stagnant. There is a further consideration, the needs of the general public, for having investigational work carried on for the use of the public generally.

Another aspect of the question is the need for independent, unselfish, unbiased attack and treatment of many research problems that otherwise would not be studied and for the fuller and more general investigation of them with a view to advancing engineering science and establishing engineering principles in lines that will be of service to mankind. Then, too, many people have some mistrust of information that comes from commercial sources, even though the research has been ably conducted. Important reasons for the support of this second class of research activity are that it will provide for an attack and study of problems otherwise overlooked or neglected, that the results may be accepted as unbiased and the conclusions as independently and judicially determined, and that the knowledge will be disseminated and be freely usable by the public.

It is evident not only that differences exist in the two classes of research problems named but that there are great differences in the nature, extent and complexity of research problems. Successful conduct of the large and complicated investigations involves having skilled insight, trained aids, experienced workers and organized activity, as well as adequate equipment and large expenditure of funds. There are, however, many minor problems, isolated or connected in some way with the larger and more complex problems, which are well worthy of attack by many institutions. Both the large and the small problem, then, may be fit subjects for investigation, the choice depending upon the aims, resources, and opportunities of the institutions.

The Engineering College and Research Activities

For the engineering college, then, many advantages may be claimed and supporting reasons given for functioning in research activities appropriate to its opportunities and facilities:

The conduct of research is an educational activity and making contributions to knowledge is a duty inherent in higher institutions of learning.

Their products of research should be accepted as non-commercial, fairly and adequately obtained, truthfully interpreted.

Among the faculty of the institutions will be men who are versed in engineering science and engineering practice and who will be able to show that they can successfully conduct research investigations in particular lines.

In most colleges the engineering equipment may be made available during the summer season and at other periods during the year. The smaller special equipment may be secured from time to time. The larger institutions will have equipment beyond that used for instruction.

The choice of problem may be varied from time to time in different industrial and construction fields, as need and opportunity exist.

Minor and preliminary problems may be taken up by faculty and students without incurring large items of expense. Even the incidental experimentation may uncover matters of importance.

Large and complex researches will be successfully handled where funds and facilities and trained investigators and competent direction are available in a manner that for many problems will be more satisfactory than the employment of a separate research instrumentality of another kind.

The student instruction should be benefited by the presence of research activity and the teaching staff will receive stimulus and incentive to better work.

As years go on the accumulated products of the work may be expected to be of real value to engineering science and the world in general.

Funds and Arrangements

The question of sources for funds for research in engineering lines, although not included in the subject of this paper, is an important matter in any discussion of research. The engineering college may have funds available for the purpose. Engineering experiment stations of state universities have conducted important research projects with funds received from state appropriations and the products of these investigations are very creditable to the stations. Other governmental agencies have conducted research very successfully. State highway departments and the United States Bureau of Public Roads have utilized very effectively available funds under their control in conducting important research work, with results that have great value. The United States Bureau of Standards, covering as it does a wide field, has made important

research contributions on a great variety of subjects with the aid of federal appropriations. In various ways governmental agencies have made valuable research contributions by means of special funds.

Other sources of financial support given to research organizations may well have recognition in this discussion. Their nature and scope may best be realized by a few examples. The important investigation of fatigue of metals at the University of Illinois was financed largely by funds contributed by the Engineering Foundation and by manufacturers interested in the phenomena of the fatigue of metals. The Portland Cement Association has for some years been providing funds for carrying on at and by the Bureau of Standards an elaborate and thorough research on the nature and properties of Portland cement as affected by raw materials and methods of manufacture, the study costing in the end probably several hundred thousand dollars—and this in addition to the outstanding work on concrete conducted in the laboratory of the Association, whose results have been given fully to the public. The research on stresses in railroad track under the joint sponsorship of the American Society of Civil Engineers and the American Railway Engineering Association, was started in 1914 with financial support from the two Societies and in the later years has been supported by contributions from steel rail manufacturers and from funds granted by the American Railway Association. The structural steel column research, carried on at the University of Wisconsin, has been supported by funds provided by the Engineering Foundation and from contributions by bridge manufacturers. The test of the Stevenson Creek Arch Dam in California, which has served to justify certain methods of analysis in the design of such structures, was made possible by large funds given by Engineering Foundation and by contributions from power companies and industrial interests in the west, and the research was made effective and scientifically successful through the coöperation of the Bureau of Standards in sending an experienced and able tester of concrete structures to conduct the testing work. In recent years the engineering experiment stations and other college research organizations have added to the amount and value of their research output by various coöperative arrangements with the industries and with engineering societies which have given financial support to projects that have the same general public character as those named above.

In such coöperative research arrangements for giving service to individuals and organizations, especially when carried out by state supported institutions, the interest of the public should be protected in some way. It is well to note some characteristics of ar-

rangements for safeguarding the value of the research to the public and upholding the independence and disinterestedness of the investigation and its findings, as required by some of the coöperating institutions. An advisory consulting committee considers the problem and the method of investigation, and may advise in the interpretation of results. The laboratory directs the investigation and controls the work and finally interprets the results and prepares the report. In general the results of the investigation are the property of the laboratory, and the institution will make first publication if the value warrants. The product of the research is generally intended to be available to the public except that a patent may be applied for if this step is thought necessary to protect the interests of the public. It is seen that the purpose of the provision is to conduct the research as an activity in such way that advantages accruing to those who have financially supported it may also be shared by others.

The matter of the financial support of research is of prime importance. To what extent it may be supported by public appropriation, by private endowment and by coöperative agreements with individuals and corporations is dependent upon many circumstances. Belief in the value of research activity must at any rate be the starting point in the consideration of sources of revenue—the proper attitude of the institutions toward research is a start in the right direction.

It would be easy to enumerate problems and projects needing investigation—large ones that would require well organized research organizations and small ones that may be conducted without large funds or elaborate equipment. This, however, is not the place for considering programs of research.

At the beginning it was noted that pioneer American engineering depended almost wholly on engineering experience, precedent, vision and judgment, and engineering science played a minor role. The increasing magnitude and difficulties of engineering projects, the need for greater permanence, economy and safety, and the greatly diversified nature of engineering work of the present day have emphasized the importance of basing engineering art more fully on engineering science. It will not be overlooked by any one that engineering will continue to need ingenuity, experience and judgment, and rules, precedent and vision, but more and more as time goes on will it be dependent on science and that accumulation of applied science that may be grouped under the term "engineering science." And should it not be accepted that it is a duty of the engineering college to contribute in a large or small way a share of the new engineering science that is needed to continue the development and growth of the engineering art that has added so greatly to the welfare of mankind.

WAYS AND MEANS OF STIMULATING RESEARCH IN ENGINEERING COLLEGES AND APPRAISING ITS VALUE

By H. V. CARPENTER

State College of Washington

President Hopkins tells us that "Education's one and overwhelming responsibility is to establish the enquiring habit of mind and a veneration for the truth." This means that if research needs stimulation, stimulation is one of our main jobs.

Human nature is so made up that the job of teaching something to the student who is not interested is most discouraging. This is still more true if we try to direct the research of a student whose interests are elsewhere. Just why it is difficult to arouse interest in research in the engineering field is hard to determine. When we see the patience, determination, enthusiasm and meticulous attention to minutia with which some of the men and women in the field of history and literature attack their problems we can only wonder why any really wide awake young embryo engineer should need to be aroused or stimulated to an interest in research. Nevertheless we find some of our students showing little interest in investigational work. Part of this is undoubtedly due to the flood of information which the technical student must master in his regular course; an amount the equivalent of which is regularly distributed over seven years in some other fields of study. In our striving to teach him all the new things in the same old four or five year course we have crowded out the thesis formerly required and have replaced it with courses which seem quite necessary. These, incidentally, require less individual contact with each student, thus showing greater apparent efficiency in the organization of our courses.

It is quite true also that most of us are awed by the great industrial laboratories. No doubt these modern institutions make it easier than ever for the teacher to accept that old and rheumatic excuse that there is no use to try to do anything since it is all being done by the men with more equipment in the big laboratories.

All of this I am quite sure has led many teachers unconsciously to slacken their efforts toward stimulation of research. Many of us need, therefore, not only to study ways through which research may be stimulated but to revamp the enthusiasm in our own souls along these lines.

We need new emphasis on the fact that the advantage to come from research work done by a student is very largely to be found

within the student himself in the development of the enquiring spirit. This curious, half doubting mind of the true investigator who accepts nothing as wholly true or quite complete until he has tested it or added some new thing to it himself is the thing we should encourage.

We need repeated over and over the fact that most of the really new discoveries have and probably always will come from the young investigator, usually in a small laboratory or none at all, who has not become too fixed in his methods of thought and who has not that dread of being mistaken that paralyzes many older workers. Pasteur, the young Edison, Bell, and countless more recent students have made worth-while discoveries, developments and contributions to fundamental theory while working amid simple surroundings. Their life stories are very much worth while. Too much perhaps we have permitted a laugh at the big corporation that pays one dollar for each new development worth patenting without our adding an explanation of the underlying conditions.

Perhaps the possibility of a job or a fellowship or other direct reward has been the only return mentioned for a bit of promising original work instead of giving a glimpse of the eternal service to mankind that follows a new discovery.

Certainly the student should understand that originality and resourcefulness are likely to lead to a job and that successful research leads to a reputation in science and technology much more promptly than routine work or teaching. However, the prospect of these rewards does not bring the inspiration for original investigation that comes from the simple urge to do the impossible or conquer the unknown and so prove one's mastery in the particular niche of nature studied.

Arousing this inner spark into the flame that burns in the soul of the real research man can come from interest in some very simple problem, if it brings the student into contact with the original papers of some brilliant worker or if it leads him to discuss it thoroughly with an inspiring investigator who is inspiring because of his own real interest in similar work. These are some of the things that bring out the inspired type of research worker. We must not overlook the somewhat more practical and perhaps we should say more up-to-date type of investigator who has developed his interest in the form of a keen determination to become thoroughly prepared for original work in his field. This seems a more reasonable type of expert than the more wild-eyed, long-haired character who will think of nothing but his own pet research. How to stimulate this saner type into proper development is hardly easy to specify. Such a man is simply a better man with longer and more thorough training than the average. His determination to

master his field can hardly be aroused while under the routine type of teacher. He must work with men who themselves are always keeping in touch with new things and so continuing their studies in the field of their teaching.

This usually leads the teacher into some research work or at least he always has research problems ready and discusses them in his class work so that the student is kept free from the ossifying notion that everything worth while has been learned.

The teachers in some freshman and sophomore courses have less opportunity perhaps to suggest research problems, yet they can at least avoid the tendency to look upon engineering and science as being in fixed and final form. Interest in research should be aroused as a part of the general awakening for the student in his junior year as he discovers that a sophomore has not quite reached the ultimate in knowledge of temporal things. Aroused as a junior he has an opportunity to do a bit of original work, at least original for him, as a senior and thus be led to go on to a more complete development either as a graduate student or in some industrial laboratory. Taking his upperclass courses without any especial interest he is likely to leave college with a stereotyped conception of certain engineering methods of doing things that will prevent his continuing growth in his profession. Such habits will lead him into the army of men who are always working for the man who does his own thinking.

All this has not touched the ways in which research can be fitted into organized courses. In spite of much scolding by teachers in non-technical divisions we are most of us guilty of offering very completely prescribed courses leaving very little opportunity for the student to choose and study any special problem. Thus where it was at one time quite common to require a thesis for the bachelor's degree now we come close to forbidding it. Sometimes an exceptional student will do additional work to make room for a bit of research. Certainly with these conditions existing or approached we cannot claim to show any great and glowing enthusiasm of the type that inspires the embryo research worker.

Of course, we all insist on some research on the part of 5 year men. Is not this sudden reversal of attitude illogical? I am sure it leaves the four-year graduate with too indefinite a notion of just what his fifth year would amount to and a doubt as to his adaptability to it. It is also true that the student is somewhat upset by the sudden change from an almost completely prescribed program to one which can be arranged to suit his own sweet will. Thus a bit more freedom seems very desirable all through the fourth year.

It seems clear that this freedom can be made more valuable by limiting it to the men who lead in scholarship. We all know the

beauty of the apple just out of reach, or the trout that requires much mountain climbing to catch. Similarly the permission to receive the individual help needed in a research problem can well be reserved for the students who show some promise, and such selection would hardly be looked upon by the student as a tendency to discourage research. Human nature works the other way.

Most of us have been trying in various ways to increase our graduate enrollment. Now we are faced with a greater increase than can be adequately handled. Heretofore our men with the master's degree have been examined quite critically by employers to make sure they were not simply low grade men who failed to get a job when first graduated. We have here a situation which gives us four good reasons for restricting severely admission to post-graduate status: First, expense; second, avoidance of wasting time on men poorly suited to the work; third, promotion of research through the competitive instinct; fourth, assurance of quality in our product. There is little doubt that we are entering a new phase in engineering education in which the master's and doctor's degrees are to become quite the common thing. Just as we have found it desirable to require special high school training both in subject matter and scholarship so it seems even more important that only the men who are best qualified for it be accepted for graduate work. This condition fits in perfectly with our need to have only a limited number of high-grade men in the graduate school if we are to achieve creditable results. Only by high-grade work can we carry over into the graduate school our hard-earned good name as a producer of good men and only in this way can our research work develop the value to society which it must have if it is to grow.

DISCUSSION OF PAPERS

A spirited and interesting discussion of these topics from the floor followed. Among those who participated in the discussion were Dean Robert C. Disque of Drexel Institute, Colonel Robert I. Rees of the American Telephone and Telegraph Company, Dean J. H. Felgar of the University of Oklahoma, Professor Raymond E. Davis of the University of California, Professor Linton E. Grinter of the A. and M. College of Texas, Dean Milo S. Ketchum of the University of Illinois, Dean Richard G. Tyler of the University of Washington, Mr. C. E. Carey of the Westinghouse Electric and Manufacturing Company, Professor F. E. Terman of Stanford University, Professor Roy A. Norman of Iowa State College, Dean Earle B. Norris of Virginia Polytechnic Institute, and Dean Charles Derleth, Jr., of the University of California. Space limita-

tions make impossible a comprehensive review of this discussion, but a few abstracts can be given.

Dean Disque: "There is a possibility of a slight inconsistency in comparing long training for the professions of law and medicine with training in graduate work beyond the four years. The fact is, it seems to me, that in law and medicine the doctors and lawyers take what we should call an extended undergraduate course rather than a postgraduate course in the academic sense, based upon an ordinary four year course."

Colonel Rees: "The point made by Dean Kimball last evening and by Dean Magnusson today is that graduate work should be founded on research, and I think we, of industry, can endorse that without reservation because what we seek in graduate students are men who have original ability, intellectual curiosity, and constructive, creative capacity. I do not see how those abilities and capacities can be discovered among graduate students unless they are given original problems in research to demonstrate their ability."

Dean Felgar: "If research is as stimulating to the student as this discussion of research is stimulating to us this morning, I am sure it is justified. . . .

"The main definition of educate, meaning 'to lead out,' justifies stimulating research for individual development. In this time of mass production in both our schools and our colleges, and with our fixed curricula there is a tendency to discourage development of individuality, and I think the opportunity to do research is an inspiration to the students who want to do something for themselves."

Professor Davis: "There is that factor of inspiration which we cannot, I think, put too much attention on, especially in our large engineering laboratories where we sometimes have independent staffs of research workers. Even though they may not be directly connected with the teaching staffs, there should be a means provided whereby both those engaged primarily in teaching and the students themselves, both graduate and undergraduate, will be brought into contact with the problems and with the workers in the research fields.

"I would like to offer the personal opinion, however, that research is not entirely confined to our laboratories, and that, so far as our engineering teachers are concerned, there is a great inspiration, one which is necessary to the highest success in teaching, that is only brought about through contact in the field. We may have just as fundamental research in connection with the actual practice of our profession in the field as in the laboratory."

Professor Grinter: "In our Texas Section a good many men

seem in favor of the five or six-year curriculum. As I understand it, they favor the inclusion of additional work in fundamentals and of practical engineering. They are not very much interested in research.

"I think that arrangement has three serious objections. In the first place, it loses the possibility of combining research with engineering teaching, and the additional stimulus to the students. In the second place, I do not feel that our institutions down there, and perhaps a great many all over the country, can afford to spend money, at the present time at least, for the teaching of engineering practice which the men can obtain in the industry, themselves. In the third place, a plan involving a five or six-year curriculum laid out all the way through misses the opportunity for selection which our present system of the four-year undergraduate course, plus graduate work, provides. It seems to me very important that we can actually discourage the very poor man and encourage the man who is capable actually of benefiting by more than four years of college work."

Dean Ketchum: "Many times we fail to appreciate that the greatest engineering experiment station is the great outdoors. That experiment station has been working from the beginning of time. We go back to the ancients five or six thousand years ago and find they have been carrying on experiments. Too seldom do we really read the results.

"I think we teachers should not wait until we get big laboratories to start research investigations. We should try to instill in our students the idea that they must keep awake all the time, that what they learn may be true today, but not true next week or next year; that they must go out and make a study of conditions and solve the problems."

Dean Tyler: "I would like to say a word about research in engineering education. It is a thing that the administrator in engineering education is very greatly interested in, and I think each of us individually should be interested in it."

Mr. Carey: "When we talk about research are we talking about engineering education to educate the student or to educate the faculty? There is no question but that the faculty men need every bit they can get of this research work to keep them on their toes. Whether research belongs to the undergraduate or not, I do not know, unless you define research a bit differently and give it a more general definition than that which has been presented here this morning.

"Apparently we look on research at this meeting as a problem for the graduate student. We look upon research as a study of a problem the solution of which is unknown. Is the solution un-

known to industry, or is it unknown to the the individual student? Certainly one that is unknown to a freshman may not be unknown to a doctor, yet if research is good for a man who is taking graduate work why is it not good for the high school student? Personally, I think research can profit when it serves only one purpose, to inspire and develop a man for individual thinking, to teach him how to use everything he knows, and to go back to fundamentals and bring those fundamentals up every time he is presented with a problem. That is the purpose of research whether in the freshman year or for graduate students."

Dean Derleth: "Our principal purpose is to train men—human beings. Some of them are worth training for four years for their own good, and no more, and there are some who can profit by research work either in the outside field, or who have peculiar talents for research in the university. Those men, a very limited number, should have graduate instruction."

REPORT OF NATIONAL RESEARCH COUNCIL COMMITTEE

Following this discussion Dean J. W. Barker of Columbia University, Chairman of the National Research Council Committee on Bridging the Gap Between the Universities and Industry, presented a report of progress of the work of the committee.

The committee considers it necessary to attempt to evaluate the research capacities of educational institutions, as to personnel, attitude of the administration, and material facilities, in order that the Division of Engineering and Industrial Research of the National Research Council may be able to lay before research directors of trade associations and of small industries, and to a lesser extent, of the large industrial laboratories, information as to where they may look for help in solving their specific problems. To accomplish this evaluation, the committee proposes:

1. That there should be convened in approximately nine different places in the United States, conferences of the various directors of research and deans of engineering, or of other specially appointed men from each of the different educational institutions, who would come to these conferences prepared to discuss and measure by a to-be-adopted yardstick for each region the research capacities of each of these various institutions; and

2. That there shall then be convened a national conference at which representatives of each of the nine district conferences shall get together and attempt to weld these yardsticks into one.

The National Research Council is considering the proposal of the committee Directors of research of the trade associations and of

the smaller industrial groups, who have been consulted, have agreed that some such method of measurement would be highly important from their point of view.

Dean D. S. Kimball of Cornell University heartily endorsed the proposal of the committee as presented by Dean Barker and moved that the proposal be approval by the conference. The motion was seconded and carried after discussions by Dean Milo S. Ketchum of the University of Illinois, Professor R. E. Davis of the University of California, Professor S. H. Graf of Oregon State College, Dean H. V. Carpenter of Washington State College, Dean O. M. Leland of the University of Minnesota, Dean H. S. Rogers of Oregon State College, and Professor B. M. Woods of the University of California.

Some extracts from these discussions follow:

Dean Kimball: "I want to approve very heartily this report. The idea of getting groups together throughout the United States is a very good thing indeed.

"This proposal is of great importance to the small industry. The large industry takes care of itself pretty well, but smaller industries throughout the United States need just this sort of thing."

Dean Ketchum: "I think it is true that every industry that has not carried on fundamental research as to its product, as to its market, and as to what it is going to do in the future, is going to the wall.

"Any industry should carry on fundamental research, and I mean fundamental. I do not mean inventions to beat the other fellow. The thing to do is to go right out in the open and have a laboratory, where they have scientific investigators to do the work in the open."

Professor Davis: "We wish to promote research, yet I believe there is a good deal of useless research going on over this country today, and a tremendous amount of duplication of effort. One of the functions of the National Research Council should be to prevent useless research as well as to promote needed research."

Dean Carpenter: "Perhaps if we had an individual problem before us we could do it just fairly well, but, as I understand it, this organization is going to make a general sweeping survey of the entire field of research. I do not know just what they are going to do, but it seems to me the only way we can do this thing will be to have a problem come up, and get together, not the deans and administrators, but the men in each institution who are supposed to know something about this subject; get them together or have them correspond and find out which man really knows something about it."

Dean Leland: "It seems to me this is a very important and commendable proposal. I think it cannot fail to produce very significant results in just getting together the information with regard to the facilities of the various educational institutions."

Dean Rogers: "In this problem of classifying schools as to their ability to carry on research, in the problem of inventorying the research facilities throughout the country, it would seem to me it would be quite an easy thing to classify physical facilities. The yardstick for the men is the big problem, and can we get a yardstick? Should we attempt to do that? Can we get a yardstick for a growing plant? You measure it to-night, and what is it tomorrow morning?

"I view with some alarm any attempt to more than bring out a classification of the accomplishments of the research men in the schools today, and through that classification indicate what they are immediately able to handle. But let us have that clearly understood in our survey, in any inventory that classifies research men, and say quite definitely, 'These men by experience have proved their ability to handle this particular kind of problem.' "

The conference adjourned at twelve thirty after about three hours of stimulating and inspiring discussions.

RESEARCH IN ENGINEERING COLLEGES OF INTEREST TO INDUSTRIES

By H. H. HIGBIE

University of Michigan

Member of S. P. E. E. Committee on Engineering Research

A compilation of subjects for investigation in colleges of engineering, suggested by representatives of industrial research organizations, was published in the Supplement to the February, 1931, issue of the JOURNAL OF ENGINEERING EDUCATION. This list resulted from a request addressed to about 150 Directors of Research in organizations listed in Bull. 60 of the National Research Council. A later list of "Industrial Research Laboratories of the United States," published in 1931 as Bulletin 81, contains at least 50 per cent more addresses, and it was considered worth while to extend the list of suggestions for research in colleges by addressing about 225 organizations which had not been approached in the earlier survey. Besides making a more definite effort to comprehend the whole field of engineering as represented in collegiate curricula, consideration was given to the probability that industries might be more ready than heretofore to suggest problems for college

work because of the curtailment of their own research on account of the business depression.

The purposes and limitations of this effort are concisely presented in the letter requesting suggestions, which was substantially as follows: "Industry should profit by some of the work done by students in engineering colleges while they are being trained in methods of research. Faculty members of universities who direct such work would generally prefer problems which are significant to industry and the professions. You could perhaps be serving your own interests as much in the end, indirectly, as you could serve the colleges now, directly, if you would take the trouble to suggest a list of subjects for investigation, which may be suitable to university or college personnel and equipment, and perhaps not likely soon to be undertaken by researchers employed in industry." This quotation may help the reader to understand some of the replies to be quoted later.

None of the suggestions published in the first compilation of replies has been repeated here. The form of presentation adopted there was made necessary by the limitations of time and space available, and some criticisms that were solicited made it appear desirable to change the form in preparing this second compilation for publication. However, as a measure of economy, the old compilation is not now being republished. Several lists of suggestions have been received which are too extensive to print here, and which the compiler does not feel competent to condense. One of these is referred to under Section R, Road and Highway Materials and Construction. Another was mentioned on page 131, Supp. to JOURNAL ENGINEERING EDUCATION, February, 1931—A Report of Survey of Protective Coating Research, published June, 1930, by American Paint and Varnish Mfrs. Association as Circular 365, forty-three pages. Another, probably typical of many which the compiler has made no effort to discover, is a pamphlet entitled "Products and Processes of Particular Interest to Us Now" published by Campbell, Peterson and Company of New York City.

No effort has been made to recast the statements made in letters that were received, as it was thought that the doubtful saving in space would not compensate the loss in flavor and character of material. If this decision results in some repetition among various companies, in defence it may be argued that emphasis has its significance and that it is desirable in every case to know who is especially interested in the question.

It has been suggested that the S. P. E. E. Committee on Engineering Research should exercise a definite supervision over at least such work as may be undertaken in response to suggestions collected and published by the Committee, so that undesirable dupli-

cation and waste of effort may be avoided. If this seems advisable and the Committee is requested to serve in such manner it probably can function, though perhaps not as effectively as the National Research Council in accordance with its custom as described under Section T of this Report.

A. Air Conditioning of Buildings; Refrigeration

46. We would suggest that the subject in which there is the most interest at the present time is air conditioning of buildings, of which there is very little known and a wide difference in opinion as to the best methods to increase the comfort and to control the temperature and humidity.

82. You are probably aware of the fact that such innovations as air conditioning for household use, for auditoriums and for industrial uses, Dry Ice and frozen foods, have appeared and are now being developed and promoted for general use and for specific applications. Of the developments we are considering, these hold, without doubt, the most far reaching and extensive possibilities.

15. There are various air cleaning and purifying devices on the market used to condition air for school and public buildings.

Dry filters comprise one group. These use cloth or other dry screens and are designed to remove dust and dirt from the air. Another group of filters use oil coated cells and are designed for same purpose. A third group consists of air washers which are designed to remove dust, fumes and gases from the air and also add moisture and maintain predetermined degrees of humidity.

Recent experiments at the Pittsburgh Research Laboratory of the A. S. H. & V. E. show that humidity control is of vital importance in air conditioning. As this is obtained by means of air washers it makes this type of filter especially desirable.

It is generally agreed that disease-producing organisms are carried on dust particles and since the air washer and humidifier is very effective in eliminating all forms of dust, the question has arisen as to whether or not a proportion percentage of bacteria is likewise eliminated.

We, therefore, suggest that research be conducted to determine how effective this above named apparatus is in eliminating harmful bacteria from the air.

We will be pleased to coöperate in this study if you desire it.

23. Then get the rest of the crowd into "air control." This is conditioning of home. It will be a larger industry than the automobile industry.

52. Another is application of air conditioning to passenger cars. Several different types have been evolved, but not perfected.

10. What are the properties and performance of the calcium chloride hygrometer? Are they accurate enough to use?

52. We find nothing yet indicating how to use dry ice for refrigeration in cars. Of course, experimentation and development are progressing, but it would appear, a thorough scientific investigation would help a lot.

B. Heating Systems and Apparatus

73. The effect of radiant energy emitted from heating apparatus upon metabolism.

The relative efficiencies of heating apparatus which warms air by convection only as compared to apparatus that emits radiant energy.

During our recent work, it has been our conclusion that the coefficients of heat transmission for building materials that are now in use have been determined by experimental processes in which radiant energy emission plays an important part. If this radiant energy emission is eliminated, the coefficients of transmission will be less than those now in use. This reduction in the coefficients of heat transmission is what we have in our laboratory termed "heating effect factor," for which we have determined a value of .7. However, the term "heating effect" is confused by practically all engineers with other factors present in the practical problem of heating a room.

If either of these subjects interest you, we will be very glad to give you any information and data which we have relative to them as a starting point for your investigation.

80. Bus heating equipment is today built by comparatively small companies and very little in the line of investigation has been done on the subject. The problem should include a study of the heat losses in different types of bodies and methods of heating, due regard being given to the amount of waste engine heat available for the purpose.

25. The relation of non-condensible gas-vapor volume to condensate in return line vacuum heating systems. That is, determination of the volume of gas vapor mixture to the condensate, to be exhausted, for a given amount of cast iron direct radiation.

A study of the same relation of non-condensible gas vapor volume to condensate to be exhausted from blast coil such as "Vento Stacks" or "Aerofin" heaters would also be of interest. Such a study would yield information that would be of very material value.

35. The joint committee on heat transmission made up of the A. S. M. E., A. S. T. M. and other engineering societies is covering the subject of heat transfer in such equipment as boilers, condensers, feedwater heaters, etc. Some of this work is being conducted by the various universities.

C. Combustion, Fuels, Fuel Oils and Fuel Gases

45. At the present time one of the problems confronting the anthracite industry is to ascertain properties that anthracite may possess which would fit it for other uses than as a fuel. Some investigation of these properties is being undertaken through the activities of the Anthracite Institute under the direct supervision of Prof. Homer G. Turner, now located at Pennsylvania State College, State College, Pa. It is probably along such lines as these that most universities would be best able to proceed in studying research questions that would concern our industry. Prof. Turner would, no doubt, furnish you with a list of studies that he is making or that he has proposed to make, and would possibly work in collaboration with you.

9. There is much to be known about the combustion of gases, as combustion in a scientific way has not been widely studied in our opinion. It is only within the last ten or fifteen years that much research concerning combustion has been conducted.

71. Method for separation of gasoline hydrocarbons into various types such as aromatics, unsaturates, etc.

Carbon deposition in internal combustion engines as a function of speed and temperature of the engine and of the viscosity, carbon residue and boiling range of the lubricating oil.

Identification of the products formed during the oxidation of lubricating oils.

Determination of the heat of cracking of various types of pure hydrocarbon compounds.

Mechanism of crystal nuclear formation and growth of wax crystals in wax bearing petroleum distillates.

Development of solvents similar to SO_2 for refining oil by solvent extraction.

Development of uses for extracted material obtained from petroleum by solvent refining processes.

Development of wax crystallization inhibitors.

Relation of sulphur content of gasoline to engine corrosion.

57. The only subject which I could have suggested to you had I been able to answer your letter promptly would be a continuation of the work started by our company some years ago on an investigation of the mechanism of the gum-forming reaction in gasoline.

11. Liquid purification. This means of removing hydrogen sulphide from gas is being extensively employed, yet the fundamental chemical reactions and the chemical constituents used in carrying out the reactions are but little known. Those reactions that are known are based primarily on what one would expect when treating an alkaline solution with hydrogen sulphide. There appears to be little direct scientific evidence as a result of research for the reactions that may occur. This applies not only to liquid purification for removal of hydrogen sulphide but to the whole field of liquid purification as now carried out in the gas industry.

Dry oxide purification. The fundamental reactions of dry oxide purification are known to a greater extent than those of liquid purification but here also the knowledge is not complete and many important factors are lacking.

Other fundamental and basic studies which require investigation include such subjects as:

The reaction and nature of coal carbonization.
Primary reactions in water gas making.
The basis of oil cracking and carburetion.
Primary reactions in combustion.

D. Purification and Cleansing of Water and Gases

76. Another line which has interested me and which is sadly in need of fundamental study are the processes of base exchange such as those used in zeolite water softening. Data are especially needed on base ex-

change equilibria. If base exchange were more widely understood I am certain that it would find a great number of practical applications.

53. The removal of small amounts of lead, zinc, copper and aluminum from water by various types of zeolites. A recent publication by Bartow & Weigle, "Industrial and Engineering Chemistry," April, 1932, pages 463–465, discusses the effect of zinc in water supplies and we think it would be of value to the public to know whether this substance can be effectively removed by zeolites. The same applies to lead, copper and aluminum, the effects of which have been investigated from time to time.

It might also be advisable to investigate fluoride removal by zeolites. Recent investigators attribute mottled teeth to the presence of fluoride in certain water supplies.

The use of manganese zeolite for removing iron from water supplies is another subject that might prove interesting. There are at present many methods for iron removal but manganese zeolite may offer possibilities for a simple method of iron removal without re-pumping and without adding oxygen. This would be particularly useful for small installations.

In connection with pressure feed devices and metering devices of various types, an orifice is used in the water line. Such orifices usually have a limited range of flow rates and it would be highly desirable to have an orifice the size of which can be readily adjusted from the outside without changing its characteristics.

The corrosion of condensate lines in heating plants, etc., is a serious problem. The admitted remedy is to slope these lines so as to drain away condensate which otherwise becomes trapped in the lines, reabsorbs oxygen and causes corrosion. However, in existing installations and often in new installations, it is impractical to make arrangements for draining condensate lines thoroughly. It would be highly desirable, therefore, to develop a substance that can be added to the steam or condensate and inhibit corrosion. Experience indicates that where oily reciprocating exhaust steam is used, return line corrosion does not take place. However, the oil contaminates the condensate and must subsequently be removed by oil removal filters before the condensate can be re-used in the boilers.

Tests on existing installations on methods of adding oil to steam which is to be used for heating purposes as a means of preventing this condensate line corrosion might be well worth while. If this oil can be successfully atomized in the steam and if it prevents the corrosion of the condensate lines, the need for Oil Removal Filters before re-using the condensate would not be a serious objection since such equipment is low in first cost and operating cost.

Another idea might be to atomize a substance like sodium silicate in the steam line and determine whether this is effective even if very small amounts of silicate are used so that they would not render the returned condensate objectionable.

24. One of the problems of future major importance in the carbon dioxide industry is the removal of odorous and objectionable impurities from by-product gases rich in carbon dioxide.

For some time to come, the greater portion of the carbon dioxide used industrially will be derived from by-product sources, such as: fermentation processes, processes for the manufacture of hydrogen, by the extraction of carbon monoxide or water gas, and from chemical processes such as the calcination of carbonates. Such by-product gases must be graded up to purities in excess of 99 per cent carbon dioxide and all impurities which are odorous, or which might be injurious in food stuffs removed.

E. Liquids and Gases: Physical and Chemical Properties; Heat Transfer, Phenomena of Flow, Etc.

27. We believe that there is also some interesting work to be done in regard to the effect on scale formation in a boiler tube, of velocity of flow through the tube and rate of heat application through the tube. Another question in the same field concerns the pressure drop in steam through small piping, say 1″ or less in diameter, at various pressures, velocities, and initial superheat, as in a superheater.

70. There are some problems which are of general interest to designers of boilers, superheaters and other heat transfer apparatus, the more complete solution of which we could take advantage of in our designs, and which, as they require extended physical research, can be considered as being beyond our scope of research activities.

Take, for instance, the problem of radiation from various gases, both luminous and non-luminous. A more complete knowledge of these laws would make it possible to more closely precalculate the performance of boilers, superheaters, oil stills, economizers, etc.

4. Heat transfer coefficients for condensing vapor (steam) under very low pressures, from 0.5 to 1 inch abs.

The effect of suspended solids on the liquid film coefficient of heat transfer inside condenser tubes. Do the suspended solids tend to rupture the stagnant film and so increase the coefficients?

Variation in the rate of solution of salts according to particle size.

The effect of agitation on the solution or leaching rate of suspended salts.

47. One of our chief interests is now and has been for some time past, the investigation of liquids suitable for filling of bellows systems for temperature control, the liquids being considered from their volatile standpoint and from their chemical reaction toward the containers in which they are placed, together with possible chemical reactions which may take place upon heating.

It has taken several years' time to acquaint ourselves with a group of liquids which will give us a possible temperature range from —50 to plus 700° F. in a series of seven or eight steps, overlapping at each end of each range to the next range above or below. You have already done some work with regard to the vapor tensions of some of the hydo-carbons, such as propane, isobutane, etc., which has been extremely valuable to us, but the work is far from being complete, as we see it. If it were possible for you or any other school to undertake a three or four year research problem of this nature in order to isolate a group of liquids which could be used for such purposes as I have mentioned, it certainly would be a

contribution to the industry, for there are ten or twelve companies and industries, at least, who are interested in the solution of problems of this sort. If this problem interests you and you decide to go ahead with anything of this kind, we shall be more than pleased to coöperate with you, by bringing to you any background which we may have, together with suggestions for this work which we might have to make from time to time with regard to the requirements of the situation as we see it.

63. Heat transfer for a mixture of liquid and vapor through tubes.

Heat transfer from condensing vapors on vertical tubes when turbulence exists in the film.

Heat transfer to boiling liquids, *i.e.*, steam and water, hydrocarbon vapor and liquid, etc.

Heat transfer from condensing vapors, both pure and impure, saturated and superheated, particularly inside tubes.

Heat transfer on the outside of tubes.

Heat transfer to liquids inside tubes and at very high Reynold's numbers.

Natural connection from various bodies, particularly liquids.

Method of determining heat transfer in radiant sections of pipe stills, boilers, etc.

Study of flow of mixture of vapors and liquid similar to problem No. 1 in Heat Transfer. Presumably this problem would be taken up in conjunction with the other so that results could be correlated.

Pressure drop inside tubes with mixtures of vapor and liquid, particularly when vapor is continuously forming, and also when chemical reaction is occurring.

Studies of the flow through filter-press cake of different physical characteristics.

Accurate data on pressure drops through staggered banks of tubes.

Mechanism and rate of corrosion of steel by oils at high temperature (free from sulphur) which is attributed to naphthenic acids—temperature range of 600° to 800° F.

6. I would suggest furthering the work which Professor Badger has done along the lines of determining heat transfer coefficients in oil refinery condensers and also research work with respect to the effect of high temperature on the properties of cast iron. If you will investigate, I believe you will find that the limited work which Professor Badger has done on heat transfer coefficients in refinery condensers is the only piece of research that has ever been undertaken along this line. I am sure that Professor Badger appreciates that the work which he has done is only in the nature of a start and that other research work along this line is desirable.

40. A study of the physical properties of typical petroleum hydrocarbons, that is: vapor pressure, specific heat, heat of vaporization, etc. Also variation of these properties with temperature and pressure.

Physical chemistry involved in typical reactions occurring in refining petroleum, especially cracking.

A study of heat transfer and pressure drop in mixtures of gases and liquids.

With special reference to the last subject, while it is possible to calculate these quantities where liquids alone or gases alone are concerned, we are very much at a loss in the case of mixtures. Practical applications are for example, the flow of a mixture of oil and gas up an oil well where gas is constantly vaporizing from the liquid, or, for example, flow through a pipe cracking still where temperature is increasing and the proportion of liquid to vapor is constantly varying.

69. Composition of crude oil.

Hydrocarbons occurring in commercial oils.

Sulphur compounds occurring in crude oil.

Nitrogen compounds occurring in crude oil.

(*Note.*—The above work is considered as a continuation and along the lines of the work conducted by Dr. Washburn in A. P. I. Project 6 and along the lines of several of the other A. P. I. Projects which have been abandoned pertaining to sulphur and nitrogen, information concerning which may be obtained from Dr. R. P. Anderson, American Petroleum Institute, 250 Park Avenue, New York City.)

Origin of crude oil.

Continuation and extension along the lines of various projects sponsored by the A. P. I. under their fundamental research program, a number of which have been discontinued due to lack of funds.

Pyrolysis of natural gas.

Pyrolysis of refinery cracking still gases.

Cracking still gases and natural gas as a source for raw materials for the chemical industry.

Solubility phenomena in connection with wax content of crude oil and commercial products.

Polymerization studies of various petroleum hydrocarbons.

Oxidation reactions of various hydrocarbons, both gaseous and liquid.

Thermodynamic properties of hydrocarbons.

Sensible heat.

Latent heat of vaporization.

Critical temperatures and critical pressures.

Variations from the gas laws.

Theoretical study of fractionation at super-atmospheric and at sub-atmospheric pressures.

Theoretical study of plant design in fractionating equipment.

Theoretical considerations of flow of heat in connection with oil to oil exchangers; oil to vapor exchangers; oil to water coolers and condensers; flue gas to oil as in pipestills, etc.

Study of chemical reactions occurring in the sulphuric acid treatment of lubricating oils and gasoline and in the use of caustic soda as a neutralizing agent after such treatment, and similar studies in the use of other acids and alkalies for similar purposes.

Study of the chemical reactions occurring in treatment and recovery of acid and alkali sludges.

I would recommend that you carefully go over the list of research projects sponsored by the A. P. I. and discontinued for the lack of funds,

all of which are important but which had to be discontinued under the existing conditions.

The work, to be of any real value, should be based on the presumption that it is to be theoretical fundamental research rather than as applied research. The industrial laboratories of the large companies are doing a tremendous amount of applied research work and it is only in the universities that fundamental research can be properly carried out.

63. The effect of temperature on rate of corrosion of steel by hydrogen sulfide in oil at high temperatures. Also the question of whether moisture has any effect on this high temperature corrosion.

The effect of hydrogen sulfide on the embrittlement of stressed tank steel and also any effect on fatigue limit.

Bubble plate operation.

A study of relative amounts of work done in spray and by bubbles for a standard design of cap with varying gas rates and liquid levels.

Effect of velocity, pressure and molecular weight on entrainment.

Specific rates of absorption of various hydrocarbons in bubble towers under known conditions of pressure and rate of flow.

Wax crystallization.

Studies of the rate of crystallization and form of crystals as affected by rate of cooling, turbulence, degree of supersaturation, etc.

64. Color in petroleum products.

Determination of the chemical nature of the coloring material in oils and motor fuels.

Development of color in petroleum products on ageing and on heating Methods for control and prevention.

Basic studies on the reactions of hydrocarbons in the silent discharge.

Analytical methods.

Accurate method of differentiating between naphthenic and paraffinic compounds.

Methods for separating olefins and diolefins from gasolines and hydrocarbon gases.

Thermal data upon the sulfur compounds found in petroleum.

F. Mechanical Equipment; Engines, Pumps, Fans; Crushing and Grinding; Dust Collection; Transport of Material

27. In our own line of work we believe that there is room for considerable additional information on questions of air and gas flow, both with respect to the fundamentals of fan design and with respect to the effect of finely divided solid material carried by a gas stream. We have in mind particularly the effect of various densities of solid material, and the particle size, shape, and density, on the frictional resistance, velocity head, and power required to move the mixture. There is also an allied field in the suspension characteristics of a moving gas stream with respect to entrained solid material, the angle of interest being the removal of the solid material from suspension.

78. The manufacture of cement may be considered a chemical engineering industry, involving nearly all of the unit processes. The principal

processes are crushing, grinding, materials handling, and the clinkering of raw mix in rotary kilns using pulverized coal, oil, or gas as fuel. The solution of any problem bearing on one of these processes should be of interest and value to the industry.

More information is needed on the behavior of finely divided solids—such as preliminary ground raw materials, raw mix, coal, and cement. Problems arise involving blending, segregation, flowing from bins, feeding devices, and the like.

81. Blast cleaning.

What is the best abrasive to use?

Is sand, metal grit, or shot more efficient under air pressures of 100 lbs. or less per square inch?

What is the cleaning rate for a given object under the above conditions?

Which of the above conditions work best for a given object to be cleaned?

What is the rate of cleaning for a given object in square feet per minute?

How far from the end of a nozzle is the greatest efficiency to be obtained with conditions as specified?

What is the best type of nozzle to be used and its life, due to the fact that this is the most perishable element in the system and the less the number of shut-downs the greater the output for a given time?

What is the cost to the user of any of the above elements, f.o.b. a given point?

We also manufacture dust arresters in connection with foundry equipment, around which many interesting problems center themselves, not only in foundry practice but many other industries as well. Therefore a few problems will be mentioned:

What is the cheapest commercial way of collecting dust at the present time, dust to run 250 mesh and up, temperature normal?

What is the cheapest method of collecting dust up to temperature of 500° F. and 300 mesh?

What form should an efficient heat exchanger take to reduce the temperature of dust ladened air to normal, or 150° F.?

What is the best method of disposing of the dust?

35. Another subject which might be of interest is the relation of drilling speed and pressure to the rate of cutting in such materials as sandstone, limestone, concrete, etc.

43. Better adhesion between steel and rubber; for instance, rubber covered steel cable which is becoming a factor in conveyor work.

The use of second waves for selective control as applied to deflectors on conveyors, power controls on pneumatic tube work, etc.

The use of low pressure air waves for similar work with that mentioned in the above paragraph.

56. Probably the most beneficial single development I can think of would be a cheap method of speed control for machine drive. The present speed control devices on the market are either extremely cumbersome and bulky, such as the Reeves drive, or are too costly.

7. Perhaps the most needed improvement at the present time is a change in transmission type that would eliminate gear clashing, provide a greater range of ratios, quick shift and silent operation. Some type of hydraulic transmission would perhaps meet all these requirements satisfactorily but it must be borne in mind that simplicity and cost are two primary considerations as well as the essentials already enumerated.

Engines which are entirely rotary instead of a combination of reciprocating and rotary motion should be developed which would permit a much greater range of operation and would require less space.

In present design of gasoline engines, it would also be desirable to have some data were it possible to obtain same, that would give constants of relation between valve and port sizes with relation to bore and stroke and speed of the engine. At the present time, this is a matter that is determined in the initial design from past experience and must then pass through a period of checking and experiments for correction to obtain proper distribution of the mixtures and other factors which are essential in producing a successful engine. So much of this work at the present time is a matter of experience and theory and there are no established relations which can be taken in an original design strictly adhered to with any reasonable assurance that the finished unit will be satisfactory.

80. Torsional vibration of crankshafts.

A great amount of work has been done on this subject by Lewis, Porter and others, but it can hardly be said that it has been completed. Thus far the work has covered only engines of slow speed. To be of benefit to the automotive industry, it is necessary that it be extended to much higher speeds. All of the published work so far done is chiefly mathematical, and there is ample opportunity to collect all this work, simplify it, and to determine the value of the constants. All of the work so far seems to start with an analysis of indicator cards, inertia forces, etc., and the calculations of critical speeds and elastic curves of the crankshafts. It should be possible to determine these various things, that are now estimated, by measurement, and probably co-relate the experimental results with the calculated and arrive at a useful solution of the problem. Tied up with this investigation are, of course, also the means of taking care of the torsional vibrations in existing shafts, such as the various kinds of dampers. This is a large problem; but not too large a one, I believe, for a man working for an advanced degree in mechanics.

G. Lubrication and Lubricants; Friction; Bearings

66. There are two outstanding problems in our industry which, in the writer's opinion, are fit subjects for research development by students in engineering colleges. Also I believe you will agree they are significant to both industry and the engineering profession.

First relates to the proper compounding of grease lubricants to meet the varied conditions of service. Available greases are usually compounded with either lime, soda or some metallic soap. The majority of them are very unstable and tend to oxidize and finally become rancid after exposure. This is especially true if they are spread out in thin layers and permitted to remain dormant for several months, as in the case of

equipment which might be stored. Considerable pressure has been brought to bear upon the grease makers during the past several years with the result that some progress has been made. My own thoughts are that some substitute should be found to replace the animal fat used in the preparation of the soap. Most authorities seem to feel that the oxidation or rancidity starts with the decomposition of the animal matter.

43. Relative merits of different greases for plain and anti-friction bearing lubrication, included among these Lubriplate, loaded oils and greases, etc.

16. Study of greases for lubrication of ball bearings and specifications of greases which will not corrode highly polished ball bearing surfaces.

65. Two suggestions occur to us which, to the best of our knowledge, have not been very extensively covered at any time up to the present. The first of these has to do with the friction in the various types of bearings. The investigation of this subject should cover ball bearings, roller bearings of both straight and taper type, and plain bearings of the various types.

The other suggestion is that of seals to be used in conjunction with ball bearing or roller bearing mountings. The investigation of this subject should, we believe, include a determination of the effectiveness of the various types of seals together with the friction introduced by each type and the limiting speed at which any particular type can be successfully applied. The types of seals investigated should cover

Felt rings.

Leather seals, including various types of commercial leather seals.

Cork seals.

The conventional stuffing box type seal.

Any other sealing device which may be available.

If either of these suggestions interest you and you decide to embark on such an investigation, we will be glad to furnish all the information we can. We feel that these two suggestions will be of very great interest not only to bearing manufacturers but also to bearing users.

64. Study of the effect of various chemical groupings on the lubricating properties of compounds.

Mechanism of the deterioration of lubricating oils in use.

H. Automotive Machinery and Materials

68. It would be my suggestion that you contact directly with the Research Committee of the Society of Automotive Engineers and endeavor to work with them as closely as possible in the work which they are doing. The program which this committee carries out is probably more representative of the immediate problems confronting the industry than any other. As an example, at the present time this committee is working on methods of determining anti-detonating properties of fuels, the corrosion of gasoline, gasoline vapor lock, the essential qualifications for a comfortable-riding automobile, practical means for determining the extreme pressure qualities of lubricants and some other problems which I do not have in mind at the present time. It is my opinion that a good deal of

this work is being concentrated at one place now, namely; the Bureau of Standards and should be distributed more widely among the various colleges of the country. In work of this kind apparent duplication is not always undesirable because it brings fresh points of view and new methods of attack into prominence.

28. We feel that one of the most profitable studies that could be made at this time would embrace a study of surface temperatures of the various parts of the combustion chamber of a modern automobile engine operated under a variety of conditions. There are many indications that future progress in the design of automobile engines depends upon the complete elimination of areas having temperatures in excess of the average temperature existing in the combustion chambers. The problem is also of importance in connection with the proper determination of the antiknock value of fuel. I believe that both the oil and automotive industries would be highly appreciative of any data that might be obtained along these lines.

31. We are very much interested in investigation pertaining to combustion chamber shapes which might be adapted to overhead valve air-cooled engines. We realize that a great amount of work has been done in combustion chamber design for water-cooled engines but all the air-cooled engines to date use the old dome combustion chamber.

We know that a group of students have many ideas along this line which perhaps would be well worth combining into a research development of this nature.

19. Research on pressure distribution during combustion in internal combustion cylinders carried out in a similar manner to the Bureau of Standards investigation of flame propagation through the combustion chamber using some development of the carbon-pile indicator in conjunction with the cathode-ray oscillograph.

Investigation of catalytic agents and "poisons" in connection with detonation suppression to substantiate or disprove forever the claims of such inventors as Dr. Sokal for his "Katalite."

Thorough investigation of "hydrogenated safety fuel" for Otto and compression ignition cycles.

Investigation of friction of internal combustion engines to attempt to formulate general expressions from which the friction of a given design could be predicted in advance.

Determination of manifold, diameters, lengths, arrangements, etc., to obtain maximum power for various numbers of cylinders and for various cylinder arrangements—inline, radial, etc.

Determine relative importance of resonant and energy conditions in "ramming" manifolds where from one to nine cylinders use common manifold and carburetor.

Determine effect of temperature of H. U. C. R. for various octane value fuels as salt filled poppet valves vs. solid metal poppet valves, or otherwise, cooled spark plugs for various temperatures of electrode, pistons with various extents of conductivities, etc.

Studies of combustion control in various overhead valve cylinders as used in aircraft engines operating on Otto cycle.

How can thermal efficiency of Otto cycle engines be improved?

What rate of pressure rise during combustion gives least torque variation consistent with best thermal efficiency for various numbers of cylinders?

80. Noise of engine exhaust and its elimination.

This is a problem which has had a surprisingly small amount of real study. There are several types of exhaust noise, but the most disturbing is probably the "cracking" at certain engine speeds. Any devices developed for the elimination of the noises should, of course, increase engine back pressure by a negligible amount.

Flow of air through engine valves.

A considerable amount of work has been done on this subject, and I do not believe that the problem merely should be a duplication of flow measurements, results of which can readily be found in the technical literature. A mathematical analysis of the whole problem, taking into consideration the valve lift diagram as compared to piston speed, would be invaluable. The effect of different valve timings should show up in an analysis of this description.

1. Determination of smallest gap (sparking voltage) required to fire various air-fuel ratios using ignitions of as many different characteristics as time for investigation permits.

Such different characteristics in the ignition circuit would be affected by different coils, harness, breakers, whether magneto or battery was used.

39. There are many unsolved problems in the automobile industry, one of the most prominent of which is a cure for what is publicly known as "shimmy." There are many technical papers of a high order on this phenomenon, in German especially, but I have never seen an analysis of this troublesome difficulty from an American university.

Another problem at present unsolved is piston rings to operate satisfactorily at engine speeds from 4,000 r.p.m. up. I can assure you there is no ring available at the present time that is suitable for this service and no technical information as to the reasons for failure under these conditions, yet both of these problems have received a tremendous amount of attention and investigation by every company in the industry for a long period of years.

As you are probably well aware, the automobile industry in general violates all the rules of good mechanical engineering in the way of bearing pressures, surface speeds, rubbing velocities and the behavior of lubricated surfaces in general. I know of no engineering information that even approximates the performance which we are daily expecting of automobile engines.

You speak especially of problems which are not likely soon to be undertaken by researchers employed in industry. You are undoubtedly familiar with the present flood of literature through technical journals regarding stream-lined cars permitting very high road speeds. There is a little hint in these writings that when such speeds are attained that there will be no brakes available which can be used with safety. The whole problem of stopping an automobile at high speeds is apparently at the present moment insoluble as any braking mechanism which is sufficiently

effective is so dangerous as to preclude its use. Some new method of stopping high speed vehicles must be devised before they can be made practical for the public. Race drivers who are familiar with cars operating at high speeds will not permit the installation of effective brakes on such a car. The abstract problem of vehicles traveling at 100 miles an hour might be a very interesting subject for a prolonged investigation.

52. One subject that looms up strongly, for the future is the application of internal combustion engines, both with mechanical and electrical drive, for switching locomotives.

23. In the automobile industry there are two problems of tremendous import: adaptation of motor to fuel oil and oxygen; and replacement of steel parts, by light metals and plastics.

I. Electrical Machines and Materials; Conductors and Insulators

58. In our opinion the most important matter waiting development is some cheap and simple method of changing direct current to alternating current. A device of this kind, which would handle from 100 to 400 watts and which could be sold at a price not to exceed $20.00, would influence the sale of several million dollars worth of other equipment. As an example, the main business sections of most communities and cities are today fed by direct current. Since these business sections spend more for advertising and need more advertising, and as neon signs are the greatest advertising medium on one's place of business today, it is necessary to install a rotary converter, which in some instances costs more than the sign, to operate said neon sign.

There is today about a million dollars worth of business in the City of Chicago alone, on neon signs, which could be closed if the price of a direct current to alternating current converter could be dropped to the price that I mentioned in the foregoing and a survey by our company shows that this holds true in practically all the important cities in the East.

I have given you the figures on only one business, but when you consider the ice box, radio, automatically cooled water filters, etc., which could be sold if a cheap source of alternating current were available, you can very readily realize just how much industry needs this development.

56. I believe that if the possibilities of the solenoid were fully developed they would have a much wider application in industry. If the solenoid could be devised to go through a predetermined cycle of motion, with a fixed force and with exact timing, it could be applied to a good many machines where cumbersome cams and mechanical devices are now necessary.

67. I believe that some important fundamental research can be carried on by engineering students on the subject of contact drop of sliding contacts. This has to do primarily with the contact drop of carbon and metal graphite brushes on commutator or slip ring electrical machinery. There are a great number of variables to affect contact drop and the influences of these variables are not distinctly understood. It would be

possible for a college student, or a number of students, to gather together the published literature on this subject and from it lay out a program of analysis by which to get a more thorough understanding of this subject.

Needless to say, this subject is of increasing importance as electrical machines are reduced in size and operated at higher peripheral speeds.

In like manner, the question of friction, or the brush riding characteristic on commutator or slip rings is important. This can well be made a separate subject of investigation or it could be coördinated with the former investigation.

18. There is one subject which I believe would be of great interest to quite a few people. This is the study of electrical resistance of ceramic and other similar products at increased temperatures and under vacuum. The radio industry is very much concerned with the problem. Some work has been done by Dr. Louis Navias of the General Electric Company, which was published in one of the recent journals of the American Ceramic Society.

61. There is some confusion in my mind as to whether you want small engineering problems or true research problems. We are not interested in the former, consequently, I will make just one suggestion which is more of the latter type, a solution of which would help the industry and increase the general knowledge of the subject.

Mechanism of Dielectric Breakdown is a very broad subject and automatically includes relationship of A.C. and D.C. breakdown for different dielectrics, and derivation of formula for calculating dielectric strength of a cylindrical condenser.

30. Electrical properties, especially dielectric strength, of varnish films and other kinds of insulating coatings at elevated temperatures, 75–125° C., and in moisture-laden atmospheres.

29. Devise a simple and practical method of measuring stray load losses in induction motors.

Devise a method of testing and calculating transient and subtransient reactances of synchronous machines.

Investigation and elimination of low power factors in the average small municipal power plant.

Torque and inrush characteristics of multiple cage and special shape windings in synchronous machine rotors.

Determine and set up values for telephone interference factors for alternators.

Investigation of iron losses in sheet steel over a wide range of densities and frequencies as are used in D.C. machines.

Determination of building up curves of exciters and alternators under control of voltage regulators.

Investigation of magnetization curves of cast steel, steel forgings, semi-steel and cast iron.

79. Methods for determining stray losses which occur in induction motors of the squirrel cage and wound rotor type.

Investigation of the different causes of noises in electric motors. Some of the causes are doubtlessly related to the slot combination and the ratio of slot mouth to air gap.

Influence of the slot combinations and air gap relations on the dead points in the starting torque of an induction motor.

Influence of the slot combinations and air gap relations on the saddle formation in the speed torque curve of induction motors.

Influence of the winding pitch on the saddle formations in the speed torque curve of single phase and polyphase motors.

Develop a method for measuring as well as calculating the free end leakage of polyphase and single phase motors. The influence of the physical dimensions of the squirrel cage on the free end leakage should be considered in this problem.

Determine the effect of the air gap on the surface losses which take place in induction motors. These are also influenced by the slot combinations, methods of machining rotor and stator surfaces and speed of the machine.

Behavior of standard motor iron under the influence of abnormally high frequencies, about 500 cycles or thereabouts corresponding to so-called tooth frequencies.

Detail study of the behavior of different type of electrolytic condensers under normal and abnormal conditions.

Behavior of single phase condenser motors under normal load conditions, that is, from no load to breakdown. This should be investigated theoretically and by tests.

Theory and tests for determining the capacity and self induction of transformer coils with particular reference to the distributed capacity which enters into the behavior of transformers when struck by lightning.

Behavior of transformers when subjected to a current impulse with particular reference to the voltage which occurs inside the transformer coils.

1. Measurements on electrical characteristics of representative commercial spark coils.

Details of double wattmeter test methods could be supplied by us.

16. Study of over-load protection devices for electric motors, to make them more accurate and more reliable.

Study of the design and characteristics of magnetic relays for use in starting and controlling electric motors.

Study of the electrical design of fan motors with single and double short circuiting shading coils, as well as the study of fan motors of the divided pole type with two windings connected to the supply circuit.

A theoretical and practical study of load losses of induction motors.

Study of added iron loss in induction motors. By added iron losses we mean, the iron losses in induction motors over and above the iron losses, which can be properly allocated according to the usual transformer method of allocating losses.

Theoretical and laboratory study of capacitor motors of various kinds, including the study of condensers, both of the electrolytic and paper insulated types. Some detailed subjects under this general subject that suggest themselves are:

Capacitor motor for elevator service.

Potential and current relays.

Study of methods of eliminating hunting or magnetic noises in the single phase motors.

Study of the variations in static torque of single phase motors of:

Commutator type.
Split phase squirrel cage type.
Capacitor type single phase motors.

J. Electrical Communication; Radio, Telephone, Telegraph; Sound

59. Below, I am suggesting a number of problems which may prove of interest to your faculty and graduate students, and which will certainly be of considerable interest to the radio industry.

Methods of measuring and measurements of the behavior of vibrating bodies, such as cone loud speaker diaphragms over the frequency range 25 to 15,000 cycles.

Study of the properties of materials under vibrational stresses at frequencies from 25 to 15,000 cycles, including viscous materials, such as rubber and alloys of metals, such as the aluminum alloys.

Study of transient phenomena in sound reproducing devices and in mechanical vibrating systems in general.

Complete study of the characteristics and properties of multi-electrode vacuum tubes, such as the pentode, under conditions of wide variations of the voltages applied to the various electrodes.

Study of the propagation of quasi-optical radio waves (between 1 and 8 meters in length), particularly with respect to variations in propagation with weather conditions, terrain, changes in the earth's magnetic field, sun-light, time of year, etc.

The above list may be brief, but I think each of these problems will constitute a large piece of work and might well be divided between several investigators.

10. Why and how does an impurity in a tone current (audible frequency) cause an error in the balancing of an alternating current bridge? Consider many kinds of a.c. bridges.

The function of magnetic leakage in the operation of the ordinary telephone receiver.

The measurement of the hysteresis loss (if any) in iron (solid or laminated) at telephonic frequencies and magnitudes of variation.

The relation of derivative permeability to steady flux density at telephonic frequencies and magnitudes.

Means for measuring the intensity of sound in air, sound of normal intensities of speech and music.

A study of radio interference, the interfering electromagnetic waves caused by a contact which makes and breaks direct current. Specifically, the plotting of the spectrum, the intensity of the radiation for each radio frequency.

A study of radio interference, same subject matter as above but directed toward the relation of the emf. and current at the contact to the intensity of the radiated wave, followed all over the spectrum produced.

Telephone traffic. If all trunks in a group are busy, what is actually

the probability that another call will be made? This should take into account only the "busy hour" of the day, and the fraction of that hour during which all trunks are busy.

41. There is, however, one line of investigation which could be carried on by your people to good advantage. That is a study of the problem of facsimile transmission looking toward the discovery of a method which would insure a much higher degree of accuracy than is at present possible and at the same time employ a much narrower frequency band in transmission than the facsimile systems now available.

The present methods now used by the telegraph companies in transmitting written messages involve a considerable amount of manual labor in the preparation of perforated transmitting tapes and in gumming and checking the messages as received on a telegraph printer. The methods which are used to check the accuracy of transmitted messages so as to avoid as far as possible any errors creeping into the delivered message are also expensive. The use of a facsimile system as a substitute for present methods would obviously reduce the labor requirements considerably and at the same time eliminate the majority of operations which introduce errors in transmission.

All of the facsimile methods thus far proposed utilize the line capacity very inefficiently. That is to say, at a given line frequency the amount of traffic which can be transmitted over a line by means of present facsimile methods is only a small fraction of that which can be transmitted by ordinary telegraph methods. The output obtainable by facsimile methods can be made equal to that of ordinary telegraph methods only by increasing the transmitted frequencies considerably above the limits set by present line construction.

I am convinced that a very much simpler and more economical method of facsimile transmission will undoubtedly be discovered, and because of the importance which I attach to the solution of this particular problem I suggest it as one for your consideration.

K. Instruments, and Control Apparatus

8. For some years, as part of this Committee's activity, Individual Committee No. 19 on Instruments and Apparatus, C. F. Hirshfeld, Chairman, has been at work on a supplementary section of these codes which is to deal with the design, construction and methods of use of instruments and apparatus employed in the testing of power plant apparatus. As this work has progressed the Committee has found that very little, if anything, is known concerning the degrees of precision obtainable with the commonly used engineering instruments and apparatus. These data are extremely important since the selection of an instrument for a particular measurement in a test should be governed to some degree by a knowledge of its precision.

It is the opinion of the Committee that many of the problems in these determinations are of such a simple character that much useful information could be accumulated through the efforts of undergraduate and graduate students desiring to devote a comparatively short time to an experimental or analytical investigation.

The Committee finds that the degree of precision obtainable with instruments commonly used by surveyors has been well determined. It knows also that quite a bit of work along the same lines has been done by the Bureau of Standards in connection with the use of mercury in glass thermometers. It is known also that a German investigator has done a considerable amount of work upon the errors frequently experienced in the use of engine indicators.

The Committee has given some thought to determining experimentally the degree of precision obtainable in the weighing of water as it is commonly done during engine and turbine tests. This study should include the effect of temperature change since the error commonly increases with the temperature. Another problem is the ordinary scale which is used in the weighing of coal or water in these tests. It is our understanding that the Bureau of Standards has done some work in the degree of precision obtainable with railroad track scales but we know of no work which has been done on the type of scale which would be used in power plant testing. Similarly, we know of no satisfactory work on the performance of pressure gages of different kinds. And so one might go on through an almost endless list. There is certainly work enough for all who care to take a hand in the solution of these problems.

If you are interested in undertaking some of the many studies hinted at above, I shall be very glad to confer with you further and to place you in direct contact with Chairman Hirshfeld and the members of the Committee most interested in the particular instruments which you are willing to investigate.

10. The relation of the response time of a direct current relay to the speed with which the air-gap magnetism rises? Consider the value of magnetic flux below which operation will not occur and above which operation will occur (statically) or the zone of such values, if it is not a line.

60. A liquid of relatively high specific gravity of good conductivity, stable and inexpensive. In other words, a substitute for mercury.

A study of the mathematics in practical aspects of the time element in control of measurable conditions such as temperature, pressure, fluid flow, etc. The greatest stumbling block in the practical application of industrial control equipment is the inability of most practical devices to take into account the degree of corrective reaction necessary and the time within which such responses should take effect.

I think you will find these two problems of very wide scope and important enough to the instrument and industrial art in general to warrant considerable effort.

37. An instrument or device for determining the softness of tissue paper, by the term softness being meant the amount of abrasive action on the hand.

1. Development of a simple and reliable shop inspection instrument to determine strength of adhesion of lacquers to metal surfaces.

L. Wood, Veneer, Paper, Boxing and Fibrous Materials

13. Although a considerable amount of information is now available regarding the thermal conductivity of the various materials, it occurs to us

that something more might be learned regarding the actual thermal conductivity of the different types of building structures in common use.

50. We are desirous of having information in regard to thin veneers.

Considerable research has been performed by the Forest Products Laboratory, Madison, Wisconsin, on wood, but, as far as we know, there is no positive data along the lines in which we are most interested. In the construction of various types of shipping containers, it is common to use very thin sheets of rotary cut lumber. In some cases, these sheets may be as thin as 1/30 of an inch. To obtain an economical container, it is becoming more and more necessary to apply exact engineering knowledge to its construction. An important element in the wooden container, of course, is the strength of the boards of which it is made. There is no question but that these boards vary widely in strength qualities, and it is highly desirable to be able to find some simple and inexpensive way to eliminate the inferior material. The problem, however, is not to make shipping containers of expensive wood, such as the structural grade of lumber, but, rather, of cheaper material which still is sound and fairly uniform in quality.

I enclose, for your guidance, copy of a report on a limited amount of research along this line, which we conducted in our own laboratory. This may give you a better picture of the problem as we see it.

43. Moisture proofing of fibre to offset physical changes due to moisture content received from handling during humid months.

M. Glass, Ceramics

44. Referring to the second problem, this is of considerable importance in the construction of many types of electric furnace heating elements. A ceramic glaze to be fired at relatively low temperatures, for instance, 1900 to 2000° F., and which will then be impervious to gases up to 1800° F.

54. Glass research problems.

Dielectric strength various thicknesses, puncture strength various thicknesses, dielectric constant various compositions.

Mechanical strength as affected by various metallic oxide content.

Fatigue effects of permanent loads below Young's Modulus.

Strength of various thicknesses of plate glass when subjected to reverberatory wind pressures, producing rapid vibrations of large plates.

Physical or crystallographic structure of glass—this is a much mooted question, and a number of careful workers are interested in it.

The actual mechanics of polishing—is it abrasion alone; highly concentrated friction heat on raised peaks of glass; or a combination of both.

Why is no other medium so satisfactory for polishing as rouge on felt?

49. One is the electrical characteristics of glass at high temperatures, for the purpose of using it, first, as an electrical interrupting and connecting medium, and, second, as a pyrometer resistance. The first application has been successfully worked out with existing commercial types of glass in connection with the control of gas. The glass is heated by the pilot flame, and as long as the pilot flame is burning the glass remains a conductor, permitting the control current to pass which turns on the gas.

As soon as the pilot light goes out the glass becomes a resistor, turning out the gas. In connection with this application, it is desirable to have the glass change its resistance rather suddenly at a given temperature. The more suddenly this change takes place, the more ideal the performance. Such a glass would open up many possibilities for electrical control.

In connection with the second application, it is desirable to have a glass which changes its resistance rather gradually, so that it could be used in connection with an ammeter to measure temperatures. The current passing through the glass under constant e.m.f. would be an indication of the temperature of the glass.

37. A method of manufacturing a softer glass.

N. Plastics, Cements, Rubber, Protective Coatings; Paints, Enamels, Finishes

44. The investigation of the complete electrical and mechanical properties of moulding materials of the type that can be readily moulded into fairly complex forms. Also the development of a material of this kind having better combined electrical and mechanical properties than any now available;

Referring to the first of these two problems, it may be said that, notwithstanding the large amount of work already done, and the excellent claims made by manufacturers of certain materials, a really satisfactory material is not yet available particularly for work at reasonably high frequencies, that is, for frequencies from, say, 10,000 to 100,000 cycles per second. Probably the best material available for general use, because of cost limitations, etc., is Isolantite, but this is not an ideal material because of limitations in producing the required shapes, and because of the hard, coarse surface structure. Something more nearly of the bakelite nature is needed, but in this material, sufficiently good dielectric properties cannot be obtained, and in this class of materials, those which are somewhat better in their electrical properties produce mouldings which are mechanically weak. While it may be possible to improve materially the mechanical strength of some of the better materials in this group, such materials would still be very much inferior electrically to a material like Isolantite.

12. Our suggestions are related to the plastic industry as a whole and should be considered from this standpoint, not restricting the studies to synthetic phenolic resins. Other plastics, such as rubber, cellulose acetate, nitrate, urea materials, etc., should be considered. In the coating field, combinations with oil films should also be included.

Specifically, our suggestions are:

A comparison and study of present methods used to determine film hardness. By film hardness we mean the films as ordinarily produced by air drying, baking, etc., on wood, metal, and other surfaces. It may be desirable to extend this study to cover other types of comparable surfaces such as laminated surfaces produced by the impregnation of paper with synthetic resin and curing with heat under hydraulic pressure.

A study of the methods of determining viscosity of plastics over a wide temperature range. Pressure should also be considered as an important

factor. Included in this field should be all present commercially used plastic materials. The relationship of surface over which the plastic flow is occurring should also be considered.

The effect of inert materials and fineness of materials on the plastic flow.

A study of the methods to determine the adherence of coatings to various surfaces. The coatings should include the general line of present day commercial varnishes and protective materials, both of the air drying and baking types. In this study may be included, although it makes the problem rather comprehensive, the relationship between the adhesion of films, plastics, etc., to surfaces and the ability of the plastic to wet the surfaces.

The influence of surface conditions on the adherence of the coating, that is the effect of absorbed gases on the adherence of films. This problem is related to the above problem but might well be separated for individual study.

The development of laboratory apparatus for the study of continuous reactions under high pressures and temperatures.

Of a strictly chemical nature, there is a definite problem in developing methods for the determination of molecular weights to high polymers—products which are present in many commercial materials.

The above problems are of sufficiently general nature that their solution should be of interest to many lines of technical endeavor. Other problems may suggest themselves from the ideas given above.

13. Reliable means to hasten the weathering effect on building materials in order to determine in advance what might be expected under normal conditions.

Liquid cement that could be poured into small orifices and provide a permanent satisfactory bond when set.

Protective coatings for wood and metal, indicating the effect on the material as well as the resistance to changes in climatic conditions.

17. "The study of the cause of jelling of asphalt paints and the elimination or control of this characteristic."

Materials such as Gilsonite seconds, some of the blown asphalts prepared by the petroleum industry and blown asphalts prepared by roofing manufacturers, when thinned down with petroleum solvents such as coal oil or naphtha have a tendency to jell on standing, to a point where the material will hardly pour from the container, although the original product was of brushing consistency. This jelling only occurs under certain conditions and so far, it has been very difficult to isolate those conditions.

This should prove an interesting problem for the research department.

If you are interested in this type of work we shall be glad to go into further details and even furnish samples of raw materials that you may need to carry on this investigation.

30. Investigation of relation of oil absorption of paint pigments to the amount of non-volatile vehicles for maximum durability. This has many phases: the various pigments, their particle size, methods of "grinding" or dispersing them, the lustre of the final finish, as applied and after

polishing, effect of various baking operations according to vehicle, the many vehicles now common. The durability itself may be either typical, an inside and outside one.

Investigation of a cycle of exposure to various weathering elements so as to approach more nearly the now customarily used "Gardner Wheel" or weatherometer in paint, enamel, varnish and lacquer testing. The present ones are such poor approximations that the present trend is toward southern exposure tests, even at their longer time demands.

49. The other problem is of a chemical nature in connection with a special concrete joint designed in our company, for leak proofing gas pipes. A special sealing method is used by which an emulsion is forced through a perforated tube into the concrete under high pressure. It is advisable to find the best possible emulsion to accomplish a permanent sealing job. At present, a soap emulsion is used with good success. Many other emulsions have been suggested and research along this line would be of great value to the industry.

9. Another problem which suggests itself would be the study of enamels or finishes for appliances that will withstand the temperature conditions and general usage to which they are subjected without failure. Vitreous enamel is brittle and is damaged rather easily. There would be quite a demand for a finish that will withstand fairly high temperatures and otherwise be satisfactory as a protective finish for appliances.

33. It seems to me that the physical constants of various types of rubber compounds might be the subject of profitable investigation. If you will look through the chapter on Rubber in the International Critical Tables, you will note that, while a considerable amount of data is available, much of it is very old, and the type of rubber compounds investigated is either indeterminate or at least varies quite widely.

Of course, the prime reason for this is that rubber compounds are constructed in almost infinite variety because of the wide variation in ingredients which is possible. Nevertheless, there are certain rather well standardized types of compounds which are now in use, and will quite likely be used without radical changes for some time to come, upon which physical constants might be determined.

It should be possible for an engineer, who contemplates the use of rubber in construction work, to get some data which will enable him to determine it's suitability to his problem. This is hardly the case at present.

The other phase of rubber investigation upon which an insufficient amount of work has been done is on the determination of the structure of rubber, both before and after vulcanization. This has been attacked by the X-ray method with what is, in my opinion, rather indifferent success. This is no criticism of the caliber of work done by the research workers but rather due to the limitation of the X-ray method itself. Optical methods of various kinds have suggested themselves as a means of attacking this problem and, doubtless, other methods would suggest themselves to the experienced physicist and physical or colloidal chemist in the universities.

O. Corrosion and Preventatives

5. A field of investigation which I feel is very important is that of developing controlled laboratory test methods for measuring rates of corrosion of various ferrous metals and other alloys. This is important because before any satisfactory progress can be made on the development of a corrosion resistant material, it is necessary to find controlled methods of test. The comparatively slow progress that has been made in the development of more satisfactory ferrous alloys of low alloy content (that is, those which offer possibilities of being in the price range of the present iron and steel) is largely due to the lack of dependable methods of testing. Test procedures should be investigated by the use of modern statistical methods as developed by Dr. W. A. Shewhart and intelligent laboratory experiments, which are so constructed as to duplicate a set of conditions similar to that which the material must meet in service.

22. It seems to me that one of the problems that might be possible for research work in the laboratories of the Universities would be along the line of corrosion of iron and steel. A great many industries would be interested in having a comparison of the protecting qualities of various types of paints. That is the type of experiment that none of the paint manufacturers like to conduct in a broad way which includes other manufacturers' products and publish the results impartially, at least, that is my conception of the situation.

Another interesting experiment would be the effect of alloying with steel various elements such as copper, molybdenum, etc. Comparison with wrought iron as commercially rolled would also be interesting.

I am suggesting the above since I feel they are good problems for research in the Universities and the results would have a very wide range of interest. It is the type of research that various Universities could conduct and compare results.

70. There is also one metallurgical problem which is of considerable interest to me, working in the heat transfer apparatus industry, and that relates to the finding of a non-corrosive ductile metal coating for steel tubes. Tubes made of high chrome alloys are neither uniformly satisfactory nor are they available at low enough prices to be generally economical. It is conceivable that by producing a durable coating of non-corrosive material which could be applied to moderately priced low carbon steel or low alloy steel tubes, the use of this tube material at elevated temperatures could be more cheaply brought about.

26. Suggest search for corrosion inhibitors, ammonia solutions in steel 20° C. to 200° C., and mechanism of magnetite formation when impurities are present. Chromates used at present.

36. We are continually confronted with problems requiring the use of metals resistant to corrosion, high temperature and high pressure. In fact chemical processes of all kinds seem to be steadily demanding the use of better alloys, higher pressures and temperatures but particularly pressures.

43. Corrosion of steel tubes—relative advantages of some of the less expensive alloys, copper—molybdenum, toncan metal, etc. In other words, relative merits of the less expensive rust resisting steels for pneumatic

tube work, dish conveyors, parts for use in dairies, restaurants, laundries, etc., where chemical action is a factor.

30. Protective coatings for magnesium alloys so as to at least compare with aluminum clad duraluminum, especially with respect to resistance to saline and alkaline mediums. Probably best by alloying or metallic coating but might include paint types.

P. Metals and Alloys

76. In the smelting of metals from their ores there is a serious dearth of thermal data on the compounds that enter into the smelting processes. Many of the data available are very inaccurate, for instance, in copper smelting a very important compound is ferrous sulphide a material which undergoes several allotropic transformations during heating and cooling, and yet the heat capacity data between room temperature and the melting point are scattered, inaccurate and almost missing in the temperature ranges where the allotropic changes take place. Also, it would be very desirable to have the heat capacity of molten ferrous sulphide. This dearth of thermal data makes it impossible to utilize effectively modern thermodynamic methods of criticising or predicting the performance of proposed innovations in pyro-metallurgy.

6. If you will note the Bolton-Bornstein article on "Effect of Elevated Temperatures on Certain Mechanical Properties of Gray Iron and Malleable Iron" as presented at the joint meeting of the American Society of Mechanical Engineers and the American Society of Testing Materials held at Chicago, June 23d, 1931, it will be apparent that considerably more research work on this very important subject is desirable.

72. Development of a better method for measuring case depth in carburized articles, particularly alloy steel.

Comparison of carbon gradation and microstructure with all of the generally used carburizing steels.

A study of the resistance to wear of the various alloy carburizing steels.

Fatigue of metals—alloys and heat treatment. When subjected to rolling loads at various speeds the effect of lubricants and oxidization.

Fatigue life of case hardened materials and other materials used in the manufacture of anti-friction bearings.

Effect of hollow roller in fatigue life.

1. Determination of difference in change in dimensions when a low carbon steel is carbonized, (*a*) in carbonizing compound, and (*b*) by gas.

30. Comparison between fatigue value of steels of same hardness but with that hardness or tensile strength arrived at by varying hardening capacities and varying tempering heats.

We ourselves are doing a very large amount of work on heat treated and un-heat treated alloy irons especially in those analyses suitable for die casting, believing that the work along these lines is going to prove of large value.

66. The second topic is one of vital interest to the industry and should be of interest to students. It has to do with the tendency of hardened steel to crack during certain grinding operations. These cracks for the most part can not be seen until the material under investigation has been

deep etched in hydrochloric or some other acid medium. This trouble has been a constant source of worry and expense to the industry for years. Much work has been done with the manufacturer of the wheels. Also of vital importance are the various cooling mediums or so-called soluble oils.

14. One of the most perplexing problems in which we are interested is concerned with a method for making quantitative measurements of the hot rollability of various copper alloys. It is known for instance, that a mixture of 60 per cent copper and 40 per cent zinc, even when contaminated with other metals such as lead will work hot over a considerable range of temperatures.

It is also known that a mixture containing 70 per cent of copper and 30 per cent of zinc will roll hot if the lead content is kept below one or two hundredths of one per cent. Hot tensile tests of these materials indicate that they possess considerable ductility while hot, as indicated by elongation and reduction of area.

On the other hand, a mixture of 90 per cent copper and 10 per cent zinc gives no difficulty in hot rolling whereas as a hot tensile test shows it to be deficient in both elongation and reduction of area. A complete investigation of this situation would be of great interest.

I am enclosing a copy of a research paper entitled 'Plasticity of Copper-Zinc Alloys at Elevated Temperatures," by a member of our organization which covers some work already done along this line.

38. Galling of metals one with the other. This is a serious problem in the oil industry as well as other industries.

Resistance to abrasion with regards rubbing together of two metal surfaces having mud for lubricant. This problem has to be met by many industries such as cement mills, mining machinery, tractors, etc.

3. There are many interesting and valuable lines of work which could be undertaken with the 35 kv.-a. high frequency converter and furnaces installed at the University of Michigan. There is also a 3 kv.-a. converter in the Physics Department which could be used for similar purposes.

For example, the student might study high temperature alloys such as those of molybdenum, tungsten, tantalum, etc. These furnaces enable one to attain extremely high temperatures under controlled gaseous conditions or under vacuum.

1. Melting point of barium metal.

Our experience over the past several years has indicated that the value given in the International Critical Tables may be far from being correct. We would be happy to supply the barium metal for such an investigation.

Vapor pressure of barium at temperatures up to 1400° C.

Effect of temperature on re-action rate of barium with CO, CO_2, H_2, O_2, N.

19. Coefficients of thermal expansion, tensile strength and fatigue limits of various aluminum, magnesium and beryllium alloys and bronzes at low and elevated temperatures.

30. Comparison of methods of determining small amounts of calcium in the presence of many times as much magnesium, for example, in commercially pure magnesium.

The separation of magnesium and aluminum borings for remelting.

84. The relation of ductility to other physical properties of welded joints, such as, tensile strength, fatigue and resistance to impact.

Impact resistance of welded joints.

Effect of annealing on the strength and other properties of welds.

Effect of annealing on locked-up stresses in welded specimens.

Effect of method of making arc and gas welds upon the ductility of the weld metal.

Relation between chemical composition (gas content) and mechanical properties of steel and the weldability.

Transference of metal in arc and gas welding with the aid of high speed motion picture cameras and other devices.

X-ray study of crystal structure of welds.

Effect of peening on the quality of welds.

Effect of method of making welds upon alloy steels and non-ferrous metals.

Investigation of the fatigue and impact resistance of welded joints to determine allowable stresses to be used in design.

Effect of the heat of welding on the adjacent metal with various alloy sheet materials.

Fundamental laws governing magnetic disturbances and how may these troubles be overcome satisfactorily.

Comparative properties of welds made with covered and bare wire.

Calorimetric study of carbon and metal arcs.

Comparative merits of various types of joints on minimizing welding strains.

The effect of coating such as paint and galvanizing on weldability.

Tests on various types of connections of beams welded to columns.

Study speed of welding and effect of amount of current.

Advantages and disadvantages of deep penetration.

Relative advantages of flash and resistance welding.

Non-destructive tests for welds.

Proper welding procedure to obtain satisfactory welds in hydrogen atmosphere.

The value of the Kinzel and Tuckerman Bend Test in determining ductility of welds.

The comparative effects of flame cut on steels of varying compositions.

Study of effect of size and shape of fillet welds on strength.

Temperatures and technique for strain annealing of various types of welds.

Temperature of oxyhydrogen-carbon monoxide flame with various ratios between hydrogen and carbon monoxide.

Temperatures of the craters of the D.C. and A.C. iron arcs in air and other gases.

The relationship between the nitride needles and physical properties of the weld.

The technique of the carburizing and nitriding of the welded metal.

Study of metal transfer by noting relative amounts of metal transferred in various positions of welding.

Comparative behavior of an arc with a pure iron electrode in argon and nitrogen and air with an arc formed by an electrode containing oxides or slag.

The effect of electrodes containing nickel and cobalt on the behavior of the arc.

Volt-ampere characteristics of an iron arc as a function of arc length.

Magnetic characteristics of various types of welded joints (for use in design of electrical machinery).

Q. Lighting, Photometry, Optics, Photoelectric Devices

20 & 21. An investigation of the rise in temperature in a room due to employment of lighting equipment of various kinds. For this purpose an investigation could be made in an office, in a classroom, in a store, and in a show window, thus taking various types of interiors. The tests should also be made with various types of lighting equipment as, for example, indirect lighting, direct lighting, enclosing glassware, etc. Some consideration, of course, would have to be given to the heat radiated by occupants of the room, to heat losses through walls, windows, floors, ceilings, etc., so that the effect of the lighting fixtures might be isolated and determined. This idea fits in more or less with thoughts on air conditioning which are occupying the minds of many of our engineers and research men today.

A similar investigation might be made of the rise in temperature in a room due to sunlight, especially in skylighted rooms, in show windows, etc. In show window practice we have had complaints from time to time regarding the melting of wax figures due to the use of artificial lighting, and upon investigation found that the affect was as much due to sunlight as to artificial lighting—more so in some cases. Of course, along with the determination of the amount of heat generated by the above means, some constructive suggestion should be made as to how to bring about a proper balance of temperature.

Investigation of the fading of delicately colored fabrics by sunlight and artificial light. Although some investigation of this kind has been made in the laboratory, I do not know of any that has been carried out in actual show windows in shops.

Another problem that is more or less interesting is the development of a means of dimming gaseous tube lighting, such as Neon, etc. No doubt some day, when gaseous tube lighting becomes more universally employed, the means of dimming will be desirable and necessary.

32. Acceptable and desirable brightness for luminous architectural elements in interior and on building exteriors.

Coefficients of utilization in rooms of various proportions and characteristics for luminous elements of various forms, sizes, and locations with reference to ceiling and walls.

In coöperation with School of Architecture the development of an illumination scheme for buildings of various types.

34. Study of the measurement of glare.

General investigation of measurable elements, and their interpretation.

Practical measurement under conditions represented by offices, factories, stores and other interiors. Verification of method outlined in A. S. A. Industrial & School Lighting Codes.

Practical measurements in streets—street lighting and automobile headlighting, highways.

Practical measurements for marine and railway conditions.

Relation of weather, wet surfaces, snow in outdoor lighting.

Application of Luckiesh-Moss card test.

Measurement of illumination.

New Weston Illuminometer—accuracy and characteristics. Color of illumination, direction, diffusion, temperature. Daylight, variant artificial illuminants.

Comparison of methods—appraisal of available instruments.

Relative seeing value different conditions—by Luckiesh-Moss card test or similar method.

Verification or criticism of recommended and safety illumination values specified—in A. S. A. Industrial & School Lighting Codes.

Measurement of ultraviolet radiation in illumination. Perhaps joint studies with medical students.

Practical methods of measurement, and interpretation in antirachitic and therapeutic values, for human beings and animals.

Physical and other measurements of ultraviolet components of light.

Reflection and transmission characteristics of various media, including glasses, reflector finishes, air, water vapor, smoke, dust.

Characteristics of available light sources and equipments.

Study of a typical room—*e.g.,* an office—with various methods of lighting—brightness, shadows, glare, footcandle values, appraisal of seeing values for specific purposes.

Diffusion of light by translucent glasses.

Verification of Ryde-Cooper formulæ (see paper Int. Ill. Congress, 1931). Practical application in illumination problems.

Criteria for purchase specification of diffusing glass globes.

Study of shadows and shades—as suggested by paper—"Schatter and Halb-schatter," by K. Norden—(Int. Ill. Congress, 1931).

Relative footcandles for equal seeing value of specified good typical conditions of natural and artificial illumination of rooms.

Artificial lighting of rooms, through skylights-economics, design of skylight, analysis of designs of lighting installations, glasses, dirt accumulations.

Study of depreciation of lamps and equipments, inherent, acquired, analysis of dirt accumulation, voltage, variation.

Survey of lighting and demand factors of typical college and school buildings.

Measure of voltage drop under various practical conditions of use.

Economic study of wiring losses, in typical school building.

Engineering recommendation for correction if desirable.

Engineering recommendation for wiring which should have been installed originally.

Comparisons with National Electrical Code and N. E. L. A. specifications.

Economic comparison of recommendations and N. E. L. A. specifications.

Engineering study of a proposed new electric lamp (selected from any available developments, heralded in the electrical press) for a manufacturer who is organizing to make such a lamp.

Built-in lighting.

Methods employed. Engineering study of available media.

Economic relations with ordinary overhead lighting for a representative room.

Tests of media and typical elements for interior and exterior use on buildings.

Street lighting.

Effectiveness for visibility, various powers of illumination, heights, spacings, transverse locations, sizes and distribution characters of illuminants.

Study of effect on lighting and visibility of street surface, curvature, forestation, adjacent buildings and including wet pavements and fog.

Study of the utilization of silhouette effect.

Experimental study of effect on illumination of group replacement (with cleaning) of lamps, as contrasted with a former haphazard maintenance. Economic relation.

Methods of appraising street lighting equipments.

Traffic signals.

General systems, various types of control, size and cp., with relation to time element of visibility and speed of traffic movement.

Effect on correct interpretation for local conditions—day and night, weather, fog, backgrounds, with reference to size and power of lights. Color blindness question.

Glare from other sources, phantom effects.

Method of appraising traffic signal units.

Engineering for thorofare traffic signal equipment, actuated automatically from side street traffic.

Engineering specification and testing of traffic signal lenses—for purchase.

Study of the legibility of sign letters. Check G. E. formula.

62. Optically precise aspheric surfaces.

The optical industry could make use of precision aspheric optical surfaces. These surfaces would necessarily be ground and polished to a specified curvature, whose cross section, instead of being a circle, would be some form of a Cartesian oval. At present, such surfaces are made, but they are not of sufficiently high quality to be used for any purpose except the condensation of light. What would be needed would be such surfaces sufficiently accurate that they could be used in such instruments as telescopes and microscopes.

Indices and Light Transmission of Isotropic Substances in the Ultra-Violet Region.

Perhaps some very useful microscope objectives could be made for use in the ultra-violet region, if we know the exact optical properties of a

number of isotropic crystals. For this purpose, it would be necessary to have available the indices of refraction for a large number of wave lengths throughout the ultra-violet spectrum, and also quantitative measurements of the amount of radiation transmitted by these substances.

Deposition of Ultra-Violet Reflecting Metals on Quartz.

It would be a great help in the manufacture of spectrographs of the Littrow type, if there were an easy method of depositing on a quartz surface, a film of metal having extremely high reflectivity in the ultra violet.

Photo-electric Cells Similar to the New Weston Cell but having Greater Sensitivity.

In many optical instruments, the eye could well be replaced by a sensitive photo-electric cell. The New Weston cell has the advantage of not requiring any B-voltage or amplifying apparatus. But, if such cells could be still more sensitive, they could be used in connection with some of the more common optical instruments such as colorimeters, photometers, etc.

Optical Glass Having New Properties.

In the optical industry, optical glasses having optical properties different than the present available glasses, would always be of advantage. Such glasses as are needed would be those having high indices and low dispersions. However, in the manufacture of microscopes, optical glass which could replace fluorite would be advantageous. Fluorite is used in the manufacture of apochromatic microscope objectives. It has a very low dispersion and a fairly low index. The industry at present, has to obtain fluorite from the natural deposits and difficulty is experienced in obtaining desirable specimens.

83. The solution of any of these problems would reduce the cost of manufacture of optical instruments:

Some alloy or process for casting, that would give us castings to which we could apply a bright lacquer finish without previously grinding the castings to a smooth surface.

Some method of electro-plating small metal parts without having to string them on a wire.

A less expensive and more rapid method of sawing glass.

The production of artificial crystals of fluorite (calcium fluoride) large enough to make lenses 2″ in diameter and ½″ thick.

Improve methods for chucking lenses for grinding and polishing.

Some method of forming on a piece of glass an optical surface without the necessity for grinding and polishing.

A reflective coating for glass that would have a high-coefficient of reflection and freedom from corrosion.

R. Road and Highway Materials and Construction

48. Under the circumstances the best thing I can do is to send you an outline of research projects which I prepared for submission to the Executive Committee of the National Crushed Stone Association, Inc., in 1930, as projects which should be undertaken in our industry.

I am also sending under separate cover a list of research projects from the Committee on Design of the Highway Research Board. (*Note:* These lists, comprising about fifty mimeographed pages, are too extensive to quote. Those interested are advised to communicate with Mr. A. T. Goldbeck, Director, Bureau of Engineering, National Crushed Stone Association, Washington, D. C.)

S. Discussion of Educational Policies and Practices

14. Permit me to state that in my judgment one of the most desirable subjects of research would be one directed to a determination of the best methods of teaching fundamental engineering subjects such as physics, mechanics, chemistry and mathematics.

39. Several dozen of technical college graduates have passed through my employ in the many years since I left school and I must emphatically state that the American college student is very poorly prepared to engage in engineering in comparison to the European graduate. I find it universally true that the American is lacking in good solid ground work in the elements of engineering mechanics, physics, chemistry and the natural laws by which the world goes around. He is not qualified to undertake designing or even drafting work properly and unless he has natural aptitudes, is not well trained for doing research. The few . . . . . men I have in the department have shown great value as executives but our engineering work is largely dependent on German, English and Austrian technical men.

I feel it is primarily the duty of the faculties of our American universities to eliminate as far as possible the shop courses, the so-called research courses, and in fact, all the so-called practical work and concentrate all effort in preparing the foundation to better advantage. At the risk of repetition let me say once again that in my opinion the business of the university is the proper training of young men in the sound fundamentals of engineering so that they will be equipped when they leave to solve the concrete problems of the industry which employs them.

75. What I say has very little importance, but I feel inclined at the same time to add that certainly in the case of undergraduate engineers I believe the time would be spent with more profit in getting as good a grounding in physics and mathematics as is possible during their course. My experience with graduates of engineering colleges leads me to the conclusion that their greatest weakness is that they do not understand either their physics or their mathematics well enough to be able to read satisfactorily the more advanced work that is being published at present in their own fields.

I realize that as an answer to your letter these remarks are entirely uncalled for, but I have a great interest in engineering education and the statement above represents a conviction that has been growing on me for some time.

42. My own experience in commercial work has emphasized the lack of ability on the part of trained men to visualize problems from more than one viewpoint, and also the lack of their ability to apply mathematical

theory to practical problems. My own experience was that under-graduate work would accomplish more in attempting what we called research problems, and which were merely attempts to duplicate things which had already been done. We did not hope to discover anything of very great value, and felt that students knowing that what they were trying to do had already been done, would not be so easily discouraged.

A few individuals having exceptional ability of an inventive nature may profitably attempt the development of something which they have conceived. This should properly come from the student himself, and any suggestion made to him would largely defeat the purpose intended.

Graduate work may be of a different character in universities. I feel that it should not be so practical as theoretical. Basic theory comes naturally from university thought, and is something which is ordinarily neglected by the majority of manufacturing concerns. The industrial research man is expected to have mastered theory, to keep in touch with new theory as it is developed, and to find practical applications for this theory. Here again the commercial research man is unable to be of great assistance, since it requires vision of an unusual nature to predict lines of profitable theoretical research.

80. I am assuming that you refer to work being done by graduate students, and if this is the case, I think that there is no question but they could do work which would be helpful to the industry. My belief, is, however, that the nature of the problems given them should be along rather narrow and very definite lines. The testing of general efficiencies of engines, trucks, etc., while it is spectacular, does not seem to be of any particular benefit to the automobile manufacturer. Practically all of the automobile manufacturers have equipment and personnel to do this kind of work much better than it can be done at colleges. Problems of a fundamental and highly theoretical nature industry has the least time for, and I believe the colleges are well fitted for work of this nature. It would, of course, have to be done under the guidance of a physicist, or a mathematician. There is another type of problem of not so fundamental and theoretical a nature which I believe could also be fitted into the program. This has to do with the products of the small manufacturers who sell accessories to the industry. These companies have neither the personnel nor the equipment for conducting any investigations, except possibly the very crudest.

77. May I make a general suggestion to the effect that you encourage teachers and students to make *critical* surveys of numerical data used in engineering—as, for instance, the mechanical and physical (thermal, electrical, etc.) properties of materials used in construction, each choosing a topic on which the equipment available to him might be used for further investigation of the topic. For it is our experience that one cannot go far in any such critical survey without raising many points upon which further information is needed. I believe therefore that there is room for a great deal of valuable work along the lines indicated and am persuaded moreover that the making of such a survey would be highly educative to those who undertake it even if it should not prove feasible to supplement the data by further laboratory investigation.

27. It is quite possible that you have reliable information with which we are not acquainted on some of these subjects, and this possibility suggests to us that one of the angles of research in universities of major importance to industry is very possibly the collection and coördination of research information already in existence. We believe that putting the information that has already been obtained on such subjects as those suggested above in collected and available form is a very valuable research activity, and further, that the preparation and proper coördination of such material as is available will immediately indicate the gaps that should be filled in order to make the data sufficiently complete for general engineering use.

47. While we are on this general subject, I should like to express my views with regard to another subject which is allied to research, and which it seems to me that the colleges as a whole do not attack in the manner best calculated to prepare the student for his life work. I refer to the fact that very few, if any, college students come into the business organizations of the country who are doing work similar to ours in general type, with sufficient background work to be of any immediate practical value to the organizations which they enter. It takes all the way from a year to four or five years to develop in these students the lines of thought and the development of ideas which will be of much value to us as employers.

It is true that the ground work is laid for the building of such lines of thought and the developing of such ideas, but it seems that the students come out of college without any preconceived ideas of how to use the knowledge which they have been accumulating. Let me illustrate a point: We have a young fellow in our organization who is the product of one of the larger engineering colleges of the country. He is a mechanical engineering graduate and is probably as well versed in thermo-dynamics, heat and its uses as any of the boys who come from any of the colleges, and yet in spite of the fact that he has been with us for two years or more, he is just beginning to wake up to the fact that it is possible to use that knowledge in the handling of design of bellows units, such as I have been describing, which are made in our manufacturing organizations. Everything that he needs to know with regard to the handling of this, he has had placed before him in college, but apparently it was only brought to him in college as having to do with steam and steam engines and that sort of thing, and not in connection with such small devices as thermostatic control.

It has seemed to me for some time and it has been the subject of discussion between myself and the Director of Research Relations at Purdue University, that colleges could better serve the industry of the nation and the states, if they were to bring the lines of study down to a more practical basis and to at least make it possible for the students to specialize in lines such as are represented in our field, for one, and in fields of a similar nature where relatively small sized mechanical units are being designed and manufactured, instead of devoting so much time to the design of power houses, large refrigerating plants and such items as that. I am sure that the industry of our state and the industries of other states would appreciate the colleges a great deal more than they do if it was possible to have the student come out with rather well-founded ideas as

to the design of small apparatus, and I think it would be just as feasible for the college to engage in this sort of education as it is to engage in that sort of education which has to do with the larger units of mechanical manufacture, such as I have mentioned.

29. We would like to see more attention given to the employment of engineering students during their summer vacations in order to give them additional training and help familiarize them with the problems which confront industry in their particular field of study. Of course, under present business conditions, such a program is practically impossible, although we feel that sooner or later industry as a whole will realize the importance of such assistance and will make some endeavor to work on some such a program year after year.

76. First of all, I wish to record some general remarks based on the fact that I have served both as a director of research with industrial concerns and as Chief Metallurgist of the U. S. Bureau of Mines in charge of numerous experiment stations. It seems to me there is a fine ethical question involved in the type of subjects that should be pursued by what I call "subsidized research organizations" such as government research laboratories and university laboratories. The spark of invention should be adequately compensated. All research is likely to stimulate invention, but it seems to me to be wrong ethically for university research to be directed immediately toward invention or problems that are certain to result in invention. Most of the university and government research, in my mind, should be directed toward collecting fundamental data and information. The above remarks deal with the ethical side of the problem and not the legal rights of university and government investigators.

27. We believe that the activities mentioned in your letter are potentially of great value, and trust that some of our suggestions may be of interest to you.

T. Coöperation of Industries and Schools

49. Your effort to obtain problems from the industry to be used as research subjects in your college is a very commendable one. In an industry like that of the Pacific Gas & Electric Company, a great many problems arise, but, for some reason, only those which require immediate solution are given attention, and a great many that might be of benefit to the industry ultimately, are not worked upon.

13. These are just a few of the problems in which we are particularly interested and would be glad to have investigated with a view to obtaining additional reliable information.

We are entirely in sympathy with what you have in mind and believe that through the facilities available in engineering colleges it should be possible to carry on work that would be mutually beneficial to the students as well as industry.

20 & 21. Your thought is a very good one, and I am sure there are many things that the students in the engineering colleges can investigate during these strenuous times; subjects which those in commercial business hesitate to devote money and effort to.

42. My own experience in college work has indicated the nature of your problem, and later experience in commercial work has answered, to a large extent, the question which you have raised, for me. If industry has problems which they feel may be solved, it is unwilling to divulge these problems because of the danger that in so doing they will minimize the possible advantage which might accrue from them. We are therefore hampered in our desire to coöperate with you in this work and cannot give you very much of value.

17. We have many problems but they specifically pertain to our special process or product and without the proper equipment and historical background the work could not be intelligently carried out by a person unacquainted with the industry. We suggest, however, the following problem, which we believe could be carried out very easily without much special equipment.

74. The problems which we have in mind combine engineering with other fields of endeavor and, consequently, any research usually requires work done outside of an engineering laboratory.

On the other hand, we are somewhat selfish in wanting to carry on our own research work in our chemical engineering laboratory, mainly because of its advertising value when completed.

82. We are not in a position to give you the information you are requesting. We would like to assist you, but do not believe we can give you precise and specific information on subjects which we are considering in the light of possible future trends in the industry.

39. I think I can speak for anyone in the industry who is frank enough to say what he feels when I say that except for a few exceptional cases we cannot wait for our problems to be solved in a somewhat abstract way in a university laboratory.

53. As a matter of fact at the present time we are pushing our research program intensively because we believe that is the most desirable course in times like these. The subjects we have mentioned above are merely a few of those which we have not yet had an opportunity to investigate thoroughly.

69. One of the chief criticisms which I have, however, of research conducted in the universities lies in the fact that the worker tries to solve a problem during the time allotted for work necessary to obtain a degree and is therefore seldom successful in turning in a real completion. If it were possible for the work to be so conducted that it could be carried on over a period of six or seven years by successive workers, I feel that much more important results would be obtained.

66. If either of these two topics appear of sufficient interest, please advise and I will be more than willing to write you in greater detail outlining our experiences and recommended procedure.

53. Should you be seriously interested in undertaking any of these problems we should be pleased to give you any suggestions we may have and to furnish you with the materials needed for the investigations.

50. While we should be interested in any research conducted along this line, we have no funds available to share in the expenses of any such undertaking.

19. We shall be interested to know if any of these investigations are actually undertaken as a result of our suggestions.

43. In conclusion we would like to say that we will be glad to work at all times with the universities and technical schools. If we have not made any worthwhile suggestions this time, may we hear from you again?

84. A great deal of our research work is carried out in governmental and university laboratories. We have found from experience that problems requiring relatively little special apparatus and considerable time on the part of the investigator lend themselves particularly to university laboratories. We have also found that problems of applied science and pure science can be handled in the university. The success of pure science research work depends very largely on the individual as well as the problem undertaken for study. As a typical example of coöperation now existing between the university and one of our projects I will take the welding investigations. This work is in charge of an Advisory Board with special committees dealing with specific subjects. In the practical investigation the work done at the university is more in the nature of testing and analysis of test results. On the other hand, we have compiled a list of more fundamental problems needing investigation, copy of which is enclosed. In this phase of our work we endeavor to secure the coöperation of leading universities to undertake specific problems. The committee assists, when called upon, in the formulation of the problem undertaken for study and in supplying specimens made up under the conditions required by the laboratory. In one or two instances we have supplied special apparatus. Once a year we bring together the university professors working on these various problems for a conference. Those laboratories that have complete reports to present are given the opportunity of presenting them before suitable meetings of the American Welding Society.

1. T. G. McDougal, Vice-President, A C Spark Plug Co., Flint, Michigan.
2. Dr. Schmidt, AGFA Ansco Corp., Binghamton, N. Y.
3. Dudley Willcox, Treasurer and Ass't Gen. Mgr., Ajax Electrothermic Corp., Trenton, N. J.
4. F. Macdonald, Technical Director, American Potash & Chemical Corp., Trona, California.
5. Anson Hayes, Director, Research Laboratories, The American Rolling Mill Company, Middletown, Ohio.
6. James W. Moore, American Cast Iron Pipe Co., Birmingham, Ala.
7. H. Walker, Chief Engineer, American LaFrance & Foamite Corp., Elmira, N. Y.
8. C. B. LePage, Sec'y to the Main Committee, American Society of Mechanical Engineers, 29 West 39th St., New York City.
9. I. V. Brumbaugh, Research Lab., American Stove Cor., 4931 Daggett Ave., St. Louis, Mo.
10. Arthur Bessey Smith, Chief Research Engineer, Associated Electric Laboratories, Inc., 1033 West Van Buren St., Chicago, Illinois.
11. Louis Shnidman, Director of Research, Rochester Gas & Electric Corp., Rochester, N. Y.
12. Archie J. Weith, Assoc. Dir., Research and Development, Bakelite Corp., 230 Grove St., Bloomfield, N. J.
13. F. H. Keyes, Bemis Industries, Inc., 40 Central St., Boston, Mass.
14. W. R. Webster, Bridgeport Brass Co., Bridgeport, Conn.

15. A. A. Criqui, Buffalo Forge Co., Buffalo, N. Y.
16. J. L. Hamilton, V. Pres. and Chief Engr., Century Electric Co., Saint Louis, Mo.
17. M. Croce, Chief Chemist, Certain-teed Products Corp., Beaver and Military Roads, Buffalo, N. Y.
18. F. H. Riddle, Director of Research, Champion Porcelain Co., Butler Ave., and Grand Trunk R. R., Detroit, Mich.
19. Robert Insley, Vice-Pres., Continental Aircraft Engine Co., 12801 East Jefferson Ave., Detroit, Mich.
20–21. J. L. Stair, Chief Engineer, Curtis Lighting, Inc., 1123 West Jackson Blvd., Chicago, Illinois.
22. W. C. Randall, Chief Engineer, Detroit Steel Products Co., 2250 East Grand Blvd., Detroit, Michigan.
23. Wm. J. Hale, Dow Chemical Co., Midland, Michigan.
24. W. M. Laughton, Sec'y, Dry Ice Corp. of America, 52 Vanderbilt Ave., New York City.
25. D. N. Crosthwait, Technical Advisor, C. A. Dunham Co., Marshalltown, Iowa.
26. Electrolux Servel, 408 East 111th St., New York City.
27. G. H. Kaemmerling, Director of Research, Erie City Iron Works, Erie, Pa.
28. Earl Bartholauent, Director Engineering Lab., Ethyl Gasoline Corp., 723 East Milwaukee Ave., Detroit, Michigan.
29. C. H. Vaupel, Mfg., Division, Fairbanks, Morse & Co., Beloit, Wis.
30. R. H. McCarroll, Ford Motor Co., 3674 Schaefer Rd., Dearborn, Mich.
31. C. T. Doman, Research Engr., H. H. Franklin Mfg. Co., Syracuse, N. Y.
32. Ward Harrison, General Electric Co., Nela Park, Cleveland, Ohio.
33. R. P. Dinsmore, Chief Chemist, Goodyear Tire & Rubber Co., Inc., Akron, O.
34. G. H. Stickney, Consulting Engr., General Electric Co., Nela Park, Cleveland, Ohio.
35. Paul D. Foote, The Gulf Companies, Research Dept., 327 Craft Ave., Pittsburgh, Pa.
36. G. M. Norman, Mgr., Hercules Powder Co., Inc., Wilmington, Delaware.
37. J. E. Harris, President, Hires, Castner & Harris, Inc., Philadelphia, Pa.
38. F. L. Scott, Engineering Dept., Hughes Tool Co., Houston, Texas.
39. Stuart G. Baits, Chief Engineer, Hudson Motor Car Co., Detroit, Mich.
40. Stewart P. Coleman, Humble Oil & Refining Co., Houston, Texas.
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45. J. S. Miller, Director of Research, Lehigh Navigation Coal Co., Lansford, Pa.
46. J. D. Harris, Executive Engineer, McCord Radiator & Mfg. Co., Detroit, Michigan.
47. Paul F. Shivers, Chief Engr., Research and Development Division, Minneapolis-Honeywell Regulator Co., Wabash, Indiana.
48. A. T. Goldbeck, Director, Bureau of Engineering, National Crushed Stone Assoc., Inc., 1735 Fourteenth St., N. W., Washington, D. C.
49. Otto A. Knopp, Chief, Bureau of Tests and Inspection, Pacific Gas & Electric Co., 4245 Hollis St., Emeryville, California.
50. Earl R. Stivers, Director, Package Research Lab., Rockaway, N. J.
51. Wm. B. Hodge, Vice-President, Parks-Cramer Co., Charlotte, N. C.

52. W. F. Kiesel, Jr., Mechanical Engr., Pennsylvania R. R., Altoona, Pa.
53. H. L. Tiger, Technical Mgr., The Permutit Co., 440 Fourth Ave., New York City.
54. R. A. Miller, Technical Sales Engr., Pittsburgh Plate Glass Co., Grant Bldg., Pittsburgh, Pa.
55. Raymond E. Miskelly, In Charge of Research Lab., Plymouth Cordage Co., North Plymouth, Mass.
56. R. J. Short, Asst. Chief Engr., The Proctor & Gamble Co., Ivorydale, Ohio.
57. C. R. Wagner, Chief Chemist, The Pure Oil Co., The Pure Oil Bldg., 35 East Wacker Drive, Chicago, Illinois.
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59. Julius Weinberger, Research Division RCA Victor Co., Inc., Camden, N. J.
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61. C. R. Boggs, Vice-Pres., Simplex Wire & Cable Co., 79 Sidney St., Cambridge, A., Boston, Mass.
62. C. A. Bennett, Acting Scientific Director, Spencer Lens Co., Buffalo, N. Y.
63. Robert E. Wilson, Standard Oil Co., 910 South Michigan Ave., Chicago, Illinois.
64. R. T. Haslam, Standard Oil Development Co., 26 Broadway, New York.
65. C. E. Morse, Engineering Dept., Standard Steel and Bearings, Inc., Plainville, Conn.
66. A. E. Fawley, Chief Engineer, Standard Steel & Bearings, Inc., Plainville, Conn.
67. V. H. Sanders, Mgr. Research and Engineering, Stackpole Carbon Co., St. Marys, Pa.
68. W. S. James, Research Engineer, The Studebaker Corp., South Bend, Ind.
69. A. E. Pew, Jr., Vice-President, Sun Oil Co., Philadelphia, Pa.
70. R. M. Ostermann, Vice-President, The Superheater Co., 122 South Michigan Blvd., Chicago, Ill.
71. L. W. Parsons, Tide Water Oil Co., 17 Battery Place, New York City.
72. O. P. Hess, Ass't to the President, The Timken Roller Bearing Co., Canton, Ohio.
73. Chester J. Scanlan, Chief Engineer, The Trane Co., LaCrosse, Wis.
74. J. F. Thompson, Supt., The Travelers, Hartford, Conn.
75. L. O. Grondahl, Director of Research, Union Switch & Signal Co., Swissvale, Pa.
76. Oliver C. Ralston, Director of Research, United Verde Copper Co., Clarkdale, Arizona.
77. John Johnston, Director of Research, United States Steel Corp., Research Laboratory, Lincoln Highway, Kearny, N. J.
78. J. C. Witt, Chemical Engineer, Universal Atlas Cement Co., 208 South LaSalle St., Chicago, Illinois.
79. H. Weichsel, Consulting Engr., Wagner Electric Corp., St. Louis, Mo.
80. Ferdinand Mehle, Research Engineer, The White Motor Co., Cleveland, O.
81. G. A. Boesger, Chief Engineer, The W. W. Sly Mfg. Co., Cleveland, O.
82. R. B. Meisenhelder, Asst. to Sales Mgr., York Ice Machinery Corp., York, Pa.
83. W. B. Rayton, Scientific Bureau, Bausch & Lomb Optical Co., Rochester, New York.
84. National Research Council, Div. of Eng'g and Industrial Research, B and 21 Sts., Washington, D. C.

The T-SQUARE PAGE

DEVOTED TO THE INTERESTS OF THE DIVISION OF ENGINEERING DRAWING

FREDERIC G. HIGBEE, EDITOR

Drawing Instruments.—At a time of economic stress when engineering freshmen are embarking upon an adventure in education and are burdened with an initial expense far exceeding that of the average college student, we are reminded that Congress has imposed a heavy tariff on drawing instruments. They have levied in fact a tax upon the American school boy. The fact that only one concern in this country makes drawing instruments, and that its product is so expensive that no school boy buys it, has had no effect upon the congressional mind. A tariff for revenue collected from freshman school boys, or a tariff for the protection of one individual, seems equally absurd.

Engineering Education.—The fact that engineering colleges have opened for another year of business as usual, the fact that enrollments are not far from normal, and the fact that a large number of engineers, graduates of previous years and not now unemployed, have returned to college to pursue graduate work, is a fine expression of confidence in the fundamental soundness of an engineering education. Even while what were formerly considered stable and secure industrial, financial, and even governmental institutions are rocking with insecurity, educational institutions are calmly and with assured certainty going about the fundamental business of education. America believes in education, and because of this belief educational institutions should feel in a deeper sense the responsibility for justifying this confidence. This also is true in a departmental sense. Engineering courses may well be inventoried during the coming year to ascertain whether or not they are accomplishing objectives in step with the times and in full accord with the respect and confidence which has been placed in them.

NEW MEMBERS

BANGS, JOHN R., JR., Professor of Administrative Engineering, Director of Personnel, Cornell University, Ithaca, N. Y. Dexter S. Kimball, Howard L. Davis.

BENFORD, WILLIAM R., Instructor in Engineering, Brown University, Providence, R. I. W. H. Kenerson, James A. Hall.

BRICK, BAYARD R., Instructor, Washington University, St. Louis, Mo. A. S. Langsdorf, Edmond Siroky.

BUECHE, H. S., Assistant Professor of Electrical Engineering, Kansas State College, Manhattan, Kansas. O. D. Hunt, R. D. Kloeffler.

COLLINS, WILLIAM L., Instructor in Theoretical and Applied Mechanics, University of Illinois, Urbana, Ill. M. L. Enger, J. O. Draffin.

DONAHUE, THOMAS L., Institute Editor, Polytechnic Institute of Brooklyn, Brooklyn, N. Y. S. A. Harbarger, H. P. Hammond.

FREUND, CLEMENT J., Dean, College of Engineering, University of Detroit, Detroit, Mich. F. A. Kartak, W. D. Bliss.

HERRICK, RAYMOND M., Professor of English, Union College, Schenectady, N. Y. J. L. Vaughan, W. F. Seamman.

HODGE, CHARLES A., Head Instructor in Electrical Engineering, Yonkers Technical High School, Yonkers, N. Y. W. S. Ayres, J. J. Estes.

HUNT, STANLEY P., Assistant Professor of Drawing and Design, University of Wyoming, Laramie, Wyo. R. S. Sink, R. L. Rhoads.

LEVENS, ALEX S., Assistant Professor of Drawing and Descriptive Geometry, University of Minnesota, Minneapolis, Minn. O. M. Leland, A. S. Cutler.

MELVIN, HAROLD W., Professor of English, Northeastern University, Boston, Mass. W. Otto Birk, J. Raleigh Nelson.

PARROTT, ALICE A., Head, English Department, Tri-State College of Engineering, Angola, Ind. J. Raleigh Nelson, S. A. Harbarger.

RICE, PAUL P., Instructor in Civil Engineering, Lafayette College, Easton, Pa. Wm. S. Lohr, Morland King, Edward H. Rockwell.

SATTERFIELD, HOWARD E., Associate Professor of Mechanical Engineering, North Carolina State College, Raleigh, N. Car. L. L. Vaughan, John M. Foster.

TAYLOR, C. FAYETTE, Professor of Aeronautical Engineering, Massachusetts Institute of Technology, Cambridge, Mass. F. L. Bishop, Nell McKenry.

THORNTON, MARMADUKE K., Professor of Chemistry and Chemical Engineering, A. & M. College of Texas, College Station, Texas. F. C. Bolton, C. W. Crawford.

TOWNSEND, ATWOOD H., Instructor in English, New York University, New York City. Philip B. McDonald, F. L. Bishop.

YENNI, WILLIAM H., Instructor in Electrical Physics, Lewis Institute, Chicago, Ill. A. D. Moore, M. B. Stout.

1933 MEETING OF THE SOCIETY

The forty-first annual meeting of this Society will be held in The Stevens Hotel, Chicago, Ill., June 27–30, 1933. This will be the fortieth annniversary of the organization of the Society which was founded at the World's Columbian Exposition in Chicago in 1893. Armour Institute of Technology will be our hosts on this occasion.

The Society will also participate in Engineers' Day, June 28, at the Century of Progress Exposition.

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